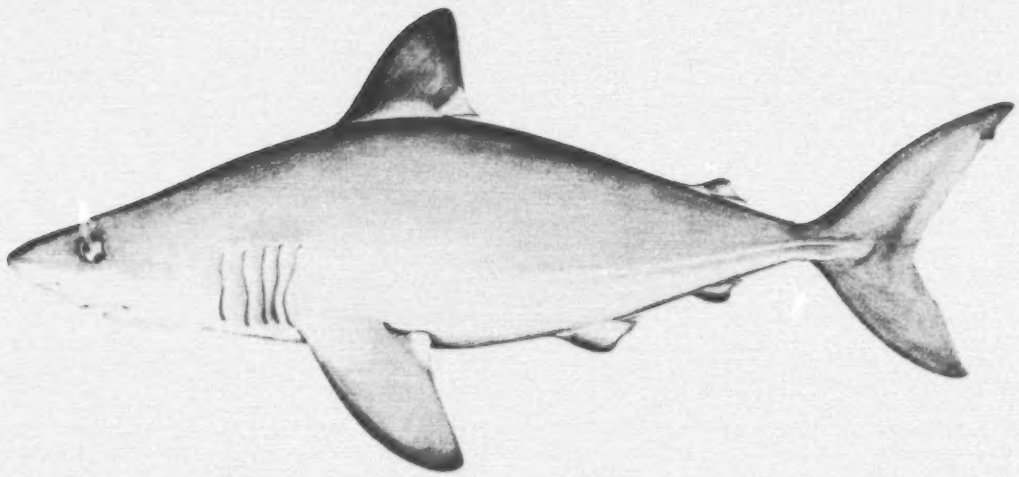
COSEWIC
Assessment and Status Report

on the

Porbeagle
Lamna nasus

in Canada



ENDANGERED
2014

COSEWIC
Committee on the Status
of Endangered Wildlife
in Canada

COSEPAC
Comité sur la situation
des espèces en péril
au Canada

COSEWIC status reports are working documents used in assigning the status of wildlife species suspected of being at risk. This report may be cited as follows:

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Previous report(s):

COSEWIC. 2004. COSEWIC assessment and status report on the porbeagle shark *Lamna nasus* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. viii + 43 pp. (www.sararegistry.gc.ca/status/status_e.cfm).

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Porbeagle — Line drawing of Porbeagle (*Lamna nasus*) from Chile, male, 81 cm total length. Drawn by M.H. Wagner from Kato *et al.* (1967). Reprinted with permission from the United States Fish and Wildlife Service.

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COSEWIC
Assessment Summary

Assessment Summary – May 2014

Common name
Porbeagle

Scientific name
Lamna nasus

Status
Endangered

Reason for designation
The abundance of this shark declined greatly in the 1960s after fisheries began targeting this species. A partial recovery during the 1980s was followed by another collapse in the 1990s. Numbers have remained low but stable in the last decade, since catch has decreased. Directed fisheries have been suspended since 2013, though there is still bycatch of unknown magnitude in Canadian waters and unrecorded mortality in international waters. This species' life history characteristics, including late maturity and low fecundity, render it particularly vulnerable to overexploitation.

Occurrence
Atlantic Ocean

Status history
Designated Endangered in May 2004. Status re-examined and confirmed in May 2014.

COSEWIC
Executive Summary

Porbeagle
Lamna nasus

Wildlife Species Description and Significance

Porbeagle (*Lamna nasus*) is one of five species belonging to the family Lamnidae, referred to as the mackerel sharks. In French, it is called maraîche. It is dark bluish grey on its dorsal side and white on its ventral side, and the free rear tip of its first dorsal fin is white, with margins that are unique to each individual. It grows to a maximum length of approximately 350 cm. It is the only representative of its genus in the Northwest Atlantic Ocean, where it occurs in a single population. It undertakes long-distance, seasonal migrations along the east coast of Canada and United States each year. There is no indication of mixing between the Northwest and Northeast populations of Porbeagle in the Atlantic. In this report, Porbeagle in the Northwest Atlantic is considered as one designatable unit. Porbeagle meat is among the most valued of shark meats.

Distribution

Porbeagle occurs in temperate waters in the North Atlantic, South Atlantic, South Pacific, South Indian and Antarctic Oceans. In the Northwest Atlantic, it ranges from northern Newfoundland and Labrador to New Jersey and possibly South Carolina, with mature females ranging farther south to the Sargasso Sea. It is widely distributed in the Canadian Atlantic and is found in the Gulf of St. Lawrence, around Newfoundland and Labrador, on the Scotian Shelf and in the Bay of Fundy. Most of the population in the Northwest Atlantic is within Canadian waters.

Habitat

Porbeagle is a cold-water species, occurring from coastal areas to the open sea, most often on continental shelves. In Canadian waters, it is encountered primarily in the deeper basins and along the shelf edge in depths less than 200 m and temperatures between 5-10°C. Mating grounds include the Grand Banks off southern Newfoundland and Labrador and Georges Bank, and pupping grounds are located in the Sargasso Sea. Porbeagle is among the deepest diving of pelagic sharks, with a maximum recorded depth of 1,360 m.

Biology

Adult females breed every year, with a gestation period of 8-9 months. In the Northwest Atlantic, they mate in the summer and early fall, and females give birth in the late winter or early spring. Litter size ranges from 2-6 pups, with an average of 3.9. Porbeagle has slow growth and late maturity, with length and age at 50% maturity of 174 cm and 8 years for males, and 217 cm and 13 years for females. These fish grow rapidly in their first year, and in the Northwest Atlantic they recruit into the fishery at age 0-1. Age has been validated up to 26 years, but they may live for more than 40 years. Natural mortality has been estimated to range from 0.10-0.20, and the generation time is 18 years.

Porbeagle is a warm-blooded shark. The presence of a vascular heat exchange mechanism allows individuals to maintain a body temperature around 7-10°C higher than ambient water temperature. They are opportunistic predators, feeding on a wide variety of prey, including fish and cephalopods.

Movement and migratory patterns of Porbeagle in the Northwest Atlantic are extensive and consistent from year to year. The fish appear in the Gulf of Maine and around the southern Scotian Shelf in late winter, move northeast to offshore basins in the spring, and reach the southern coast of Newfoundland and Labrador and the Gulf of St. Lawrence in the summer and fall. A return movement to the southwest occurs in late fall, with mature females migrating farther south to the Sargasso Sea in the winter.

Population Sizes and Trends

The total 2009 Porbeagle abundance has been estimated to be approximately 197,000-207,000 individuals, including about 11,000-14,000 spawning females. The total population biomass was estimated to be 10,000 metric tonnes for the same year. Since 1961, the abundance of spawning females and total abundance have declined by about 74-77% and 56-70%, respectively. Population decline appears to have halted over the past decade, as fisheries were reduced. Population recovery has been predicted to occur on the order of decades if incidental mortality rates are kept less than 4% of the vulnerable biomass.

Threats and Limiting Factors

Overfishing of Porbeagle in the Northwest Atlantic in the 1960s and again in the 1990s led to two successive population collapses. In Canada, landings were first restricted by quotas in 1998, and were less than 100 tonnes annually from 2009 to 2011. The directed fishery was discontinued in 2013. However, Porbeagle is still taken as bycatch in swordfish and tuna longline fisheries, and in groundfish longline fisheries, gillnet and bottom trawl fisheries. In Atlantic Canada, Porbeagle discards remain unrecorded in most of the fisheries statistics, except for those collected by Canadian Fisheries Observers. There is little information on Porbeagle catches outside Canada. Unknown and unregulated catches may undermine population recovery.

Protection, Status, and Ranks

In Canada, Porbeagle is managed based on stock assessments, and directed fishing was not permitted in 2013. In 2004, COSEWIC assessed Porbeagle as Endangered using criterion A2bd, though it was not listed under the *Species at Risk Act* (SARA) because of economic losses associated with eliminating the directed fishery. Reduced catch levels were thought to be low enough to avoid jeopardizing the long-term recovery of the species. The IUCN lists Porbeagle as Vulnerable (A2bd+3d+4bd) because of its low reproductive capacity and high commercial value. In 2013, Porbeagle was listed on Appendix II of the Convention on International Trade in Endangered Species of Wild Flora and Fauna (CITES).

TECHNICAL SUMMARY

Lamna nasus
Porbeagle Maraîche
Range of occurrence in Canada (province/territory/ocean): Atlantic ocean; continental shelves and offshore from Newfoundland and Labrador to the Bay of Fundy including the Gulf of St. Lawrence

Demographic Information

Generation time (usually average age of parents in the population; indicate if another method of estimating generation time indicated in the IUCN guidelines (2008) is being used)	18 yrs
Is there an [observed, inferred, or projected] continuing decline in number of mature individuals?	No
Estimated percent of continuing decline in total number of mature individuals within [5 years or 2 generations]	Not applicable
[Observed, estimated, inferred, or suspected] percent [reduction or increase] in total number of mature individuals over the last [10 years, or 3 generations].	74-77% decline (estimated for mature female abundance from 1961 to 2009, 2.6 generations)
[Projected or suspected] percent [reduction or increase] in total number of mature individuals over the next [10 years, or 3 generations].	Not done
[Observed, estimated, inferred, or suspected] percent [reduction or increase] in total number of mature individuals over any [10 years, or 3 generations] period, over a time period including both the past and the future.	Not done
Are the causes of the decline clearly reversible and understood and ceased?	No
Are there extreme fluctuations in number of mature individuals?	No

Extent and Occupancy Information

Estimated extent of occurrence	1,313,000 km²
Index of area of occupancy (IAO) (Always report 2x2 grid value).	>2,000 km²
Is the population severely fragmented?	No
Number of locations*	Not applicable
Is there an [observed, inferred, or projected] continuing decline in extent of occurrence?	No
Is there an [observed, inferred, or projected] continuing decline in index of area of occupancy?	No
Is there an [observed, inferred, or projected] continuing decline in number of populations?	No
Is there an [observed, inferred, or projected] continuing decline in number of locations*?	Not applicable
Is there an [observed, inferred, or projected] continuing decline in [area, extent and/or quality] of habitat?	No
Are there extreme fluctuations in number of populations?	No
Are there extreme fluctuations in number of locations*?	Not applicable

*See Definitions and Abbreviations on the COSEWIC website and IUCN 2010 for more information on this term.

Are there extreme fluctuations in extent of occurrence?	No
Are there extreme fluctuations in index of area of occupancy?	No

Number of Mature Individuals (in each population)

Population	N Mature Individuals
Total	11,339-14,207 (number of spawning females in 2009)

Quantitative Analysis

Probability of extinction in the wild is at least [20% within 20 years or 5 generations, or 10% within 100 years].	Slow recovery is predicted, if levels of fishing mortality are low

Threats (actual or imminent, to populations or habitats)

Fisheries are the largest threat to Porbeagle in the Northwest Atlantic. Overfishing in the 1960s and again in the 1990s resulted in two population collapses. The directed fishery for Porbeagle was not permitted in 2013 leaving all current threats restricted to bycatch fisheries.

Rescue Effect (immigration from outside Canada)

Status of outside population(s)?	Not assessed
Is immigration known or possible?	Possible from US, but most fish travel through waters of both countries
Would immigrants be adapted to survive in Canada?	Unknown
Is there sufficient habitat for immigrants in Canada?	Yes
Is rescue from outside populations likely?	No

Data-Sensitive Species

Is this a data-sensitive species?	No

COSEWIC Status History

Designated Endangered in May 2004. Status re-examined and confirmed in May 2014.

Additional Sources of Information: 2004 COSEWIC report

Status and Reasons for Designation:

Status:	**Alpha-numeric code:**
Endangered	A2b

Reasons for designation:

The abundance of this shark declined greatly in the 1960s after fisheries began targeting this species. A partial recovery during the 1980s was followed by another collapse in the 1990s. Numbers have remained low but stable in the last decade, since catch has decreased. Directed fisheries have been suspended since 2013, though there is still bycatch of unknown magnitude in Canadian waters and unrecorded mortality in international waters. This species' life history characteristics, including late maturity and low fecundity, render it particularly vulnerable to overexploitation.

Applicability of Criteria

Criterion A (Decline in Total Number of Mature Individuals): Meets Endangered A2b because the abundance of mature females has declined by 74-77% over the past 2.6 generations. Although the directed fishery has been suspended, the species continues to be taken as bycatch in a variety of other fisheries.

Criterion B (Small Distribution Range and Decline or Fluctuation): Does not apply because the extent of occurrence greatly exceeds 20,000 km^2 and the index of area of occupancy greatly exceeds 2,000 km^2.

Criterion C (Small and Declining Number of Mature Individuals): Does not apply because the number of mature individuals exceeds 10,000.
Criterion D (Very Small or Restricted Population): Does not apply because the number of mature individuals greatly exceeds 1,000, the index of area of occupancy greatly exceeds 20 km^2, and there may be more than 5 locations.
Criterion E (Quantitative Analysis): Does not apply because the population is not predicted to decline if fishing mortality remains low.

PREFACE

Since the preparation of the previous COSEWIC status report on Porbeagle in 2004 (COSEWIC 2004), several new studies have been conducted on Porbeagle in the Northwest Atlantic Ocean. A satellite tracking study has identified a Porbeagle pupping ground in international waters, with mature females migrating as far as 2,356 km south to the Sargasso Sea in winter to give birth there in the spring. The same study also found Porbeagle to be among the deepest diving of pelagic sharks, and recorded mature females at depths of up to 1360 m. Catches of Porbeagle in Newfoundland and Labrador waters have indicated that its range extends slightly farther north along the coast than documented in the previous COSEWIC report. This in part has resulted in the extent of occurrence of Porbeagle increasing from 1,210,000 km^2 to 1,313,086 km^2. In 2006, the IUCN changed its listing of Porbeagle from Lower Risk/Near Threatened to Vulnerable. In 2013, Porbeagle was listed on Appendix II of CITES. The directed fishery for Porbeagle in Canada was not permitted in 2013.

COSEWIC HISTORY

The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) was created in 1977 as a result of a recommendation at the Federal-Provincial Wildlife Conference held in 1976. It arose from the need for a single, official, scientifically sound, national listing of wildlife species at risk. In 1978, COSEWIC designated its first species and produced its first list of Canadian species at risk. Species designated at meetings of the full committee are added to the list. On June 5, 2003, the *Species at Risk Act* (SARA) was proclaimed. SARA establishes COSEWIC as an advisory body ensuring that species will continue to be assessed under a rigorous and independent scientific process.

COSEWIC MANDATE

The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) assesses the national status of wild species, subspecies, varieties, or other designatable units that are considered to be at risk in Canada. Designations are made on native species for the following taxonomic groups: mammals, birds, reptiles, amphibians, fishes, arthropods, molluscs, vascular plants, mosses, and lichens.

COSEWIC MEMBERSHIP

COSEWIC comprises members from each provincial and territorial government wildlife agency, four federal entities (Canadian Wildlife Service, Parks Canada Agency, Department of Fisheries and Oceans, and the Federal Biodiversity Information Partnership, chaired by the Canadian Museum of Nature), three non-government science members and the co-chairs of the species specialist subcommittees and the Aboriginal Traditional Knowledge subcommittee. The Committee meets to consider status reports on candidate species.

DEFINITIONS
(2014)

Wildlife Species	A species, subspecies, variety, or geographically or genetically distinct population of animal, plant or other organism, other than a bacterium or virus, that is wild by nature and is either native to Canada or has extended its range into Canada without human intervention and has been present in Canada for at least 50 years.
Extinct (X)	A wildlife species that no longer exists.
Extirpated (XT)	A wildlife species no longer existing in the wild in Canada, but occurring elsewhere.
Endangered (E)	A wildlife species facing imminent extirpation or extinction.
Threatened (T)	A wildlife species likely to become endangered if limiting factors are not reversed.
Special Concern (SC)*	A wildlife species that may become a threatened or an endangered species because of a combination of biological characteristics and identified threats.
Not at Risk (NAR)**	A wildlife species that has been evaluated and found to be not at risk of extinction given the current circumstances.
Data Deficient (DD)***	A category that applies when the available information is insufficient (a) to resolve a species' eligibility for assessment or (b) to permit an assessment of the species' risk of extinction.

* Formerly described as "Vulnerable" from 1990 to 1999, or "Rare" prior to 1990.

** Formerly described as "Not In Any Category", or "No Designation Required."

*** Formerly described as "Indeterminate" from 1994 to 1999 or "ISIBD" (insufficient scientific information on which to base a designation) prior to 1994. Definition of the (DD) category revised in 2006.

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The Canadian Wildlife Service, Environment Canada, provides full administrative and financial support to the COSEWIC Secretariat.

COSEWIC Status Report

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Porbeagle

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2014

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WILDLIFE SPECIES DESCRIPTION AND SIGNIFICANCE

Name and Classification

Porbeagle (*Lamna nasus*) belongs to the class Chondrichthyes and the order Lamniformes. It is one of five species belonging to the family Lamnidae, a group referred to as the Mackerel sharks, and is the only representative of the genus *Lamna* in the Northwest Atlantic Ocean. It was first described by Bonnaterre in 1788. The name Porbeagle is thought to derive from the Cornish "porgh-bugel", likely from a combination of "porpoise" for its shape and "beagle" for its hunting prowess (http://www.flmnh.ufl.edu/fish/Gallery/Descript/Porbeagle/Porbeagle.html). Other common names include Atlantic mackerel shark, Beaumaris shark, bottle-nosed shark and blue dog. In French, Porbeagle is referred to as maraîche.

Morphological Description

Porbeagle is dark bluish grey to bluish black on its dorsal side and white on its ventral side, and has a white tip on the lower trailing edge of its first dorsal fin, with margins that are unique to each individual (Scott and Scott 1988; Compagno 2001). Maximum total length is approximately 350 cm (Campana *et al.* 1999). Its first dorsal fin is large, triangular and about as high as it is long (Figure 1; Compagno 2001; Branstetter 2002). Its second dorsal and anal fins are small, and the origin of its second dorsal fin is directly above the origin of its anal fin (Branstetter 2002). It has strong keels on its caudal peduncle, and a smaller secondary keel on the lower half of its caudal fin, which is a unique characteristic of this species (Compagno 2001). Its caudal fin is crescent-shaped, with the lower lobe two-thirds to three-quarters as long as the upper lobe (Compagno 2001; Branstetter 2002). Its pectoral fins are large and twice as long as they are broad (Scott and Scott 1988). Porbeagle has a heavy and spindle-shaped body, a stout head, a pointed snout, large, black eyes and small, smooth-edged, narrow teeth, with 1 cusp at the base on each side of the tooth (Scott and Scott 1988; Compagno 2001). Its teeth have lateral denticles (tricuspid) and are similar in the upper and lower jaws (Compagno 2001).

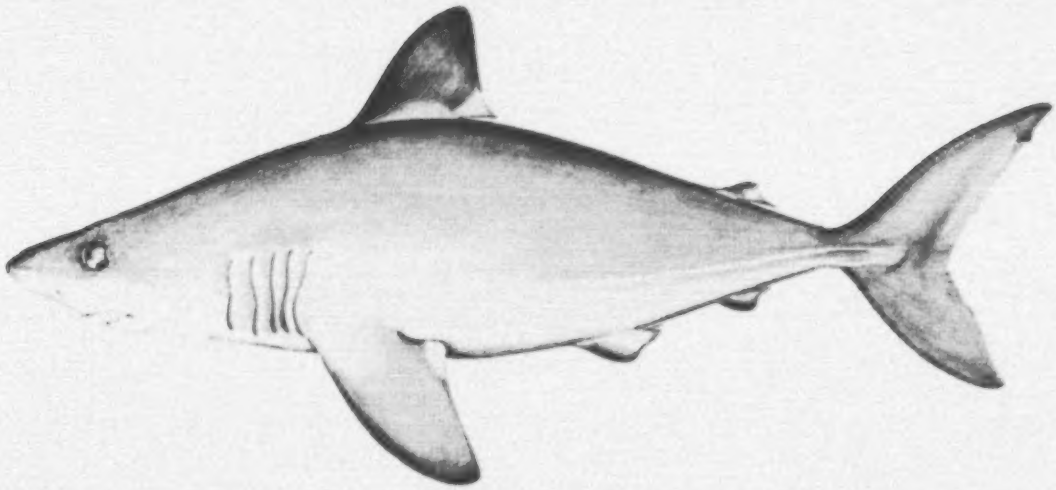

Figure 1. Line drawing of Porbeagle (*Lamna nasus*) from Chile, male, 81 cm total length. Drawn by M.H. Wagner from Kato *et al.* (1967). Reprinted with permission from the United States Fish and Wildlife Service.

Population Spatial Structure and Variability

There is strong evidence to suggest that there is only one population of Porbeagle shark in the Northwest Atlantic. These fish undertake extensive migrations up and down the east coast of Canada and United States (US) each year (Campana *et al.* 1999, 2001). Several tagging studies were carried out in the Northwest Atlantic from the 1960s to 1990s, with over 200 recaptures reported (Campana *et al.* 2012). None of the tagged fish were recaptured on the eastern side of the Atlantic, and only one Porbeagle tagged in the eastern Atlantic was recaptured off the Northwest Atlantic coast (Stevens 1990; Francis *et al.* 2008). Therefore, fish from the Northwest and Northeast Atlantic belong to separate populations (Campana *et al.* 1999).

Designatable Units

Because previous research indicates that there is only one population of Porbeagle in the Northwest Atlantic (Campana *et al.* 1999, 2001), Porbeagle is considered as one designatable unit in this report.

Special Significance

Porbeagle occupies a high trophic level (Cortés 1999) and is an opportunistic predator, feeding on a wide range of teleost species, as well as cephalopods (Joyce *et al.* 2002). This suggests that it may play an important ecological role in structuring marine communities. In the Northwest Atlantic, fishers started targeting Porbeagle in the early 1960s due to its high quality meat (Fleming and Papageorgiou 1997; Fowler *et al.* 2004). There was a directed fishery in Atlantic Canada until 2013, with low catches in recent years (Campana *et al.* 2012). In the early nineteenth century, Porbeagle was in great demand for its liver oil, which was primarily used for tanning purposes (Bigelow and Schroeder 1948). Porbeagle meat is one of the most highly valued of shark meats and is widely sold by sashimi-grade tuna and swordfish dealers, with the quality of the meat often compared to that of swordfish (Rose 1998; Vannuccini 1999).

DISTRIBUTION

Global Range

Porbeagle occurs mainly within the latitudinal bands of 30-70°N and 30-50°S (Francis *et al.* 2008; Last and Stevens 2009). It occupies a circumglobal band of temperate water throughout the southern hemisphere (Figure 2; Compagno 2001). In the Northwest Atlantic, it ranges from northern Newfoundland and Labrador in Canada to New Jersey and possibly South Carolina in the US (Bigelow and Schroeder 1948; Templeman 1963; Cassoff *et al.* 2007). In the eastern Atlantic, it is found off Iceland, Europe, northern Africa and in the Baltic and Mediterranean seas (Gauld 1989; Stevens 1990; Compagno 2001; Storai *et al.* 2005). In the southern hemisphere, it occurs off southern Brazil, Argentina and Chile (Kato *et al.* 1967; Nakaya 1971; Menni and Gosztonyi 1977), off South Africa and throughout the southern Indian Ocean (Bass *et al.* 1975; Duhamel and Ozouf-Costaz 1982) and off southern Australia, New Zealand and Antarctica (Svetlov 1978; Stevens *et al.* 1983; Last and Stevens 2009). There is no information to indicate that the historical distribution of Porbeagle differed from its present distribution.

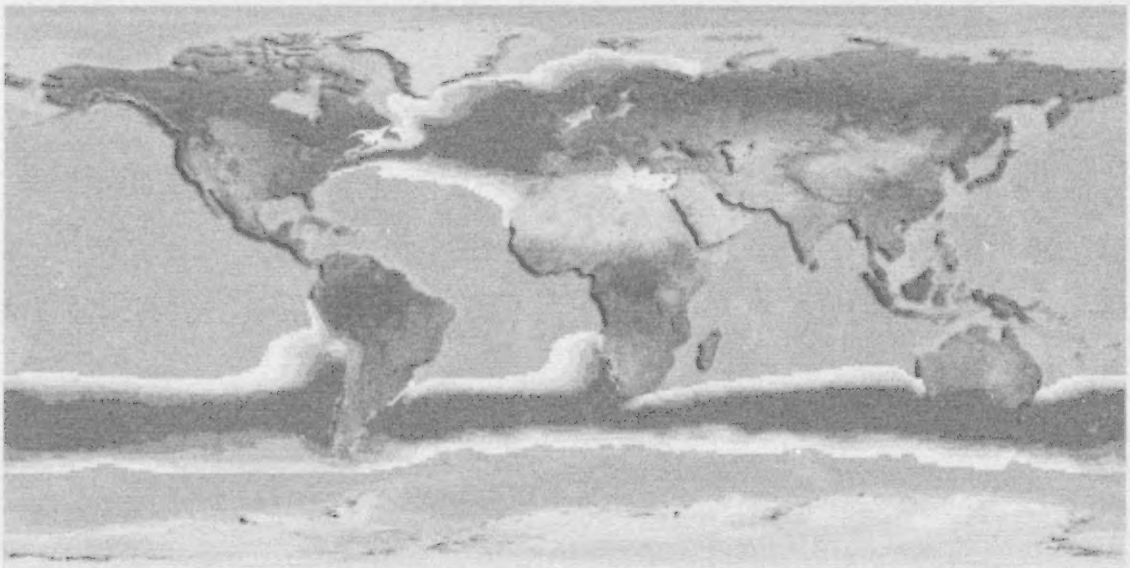

Figure 2. Global range of Porbeagle. Red shading indicates highest probability of occurrence. From FishBase (www.fishbase.org).

Recent research has identified a Porbeagle pupping ground in the Sargasso Sea, extending the known southern range of this species in the Northwest Atlantic from 37°N to approximately 21°N (Figure 3; Campana *et al.* 2010).

Canadian Range

In Canada, Porbeagle is distributed continuously along the east coast from northern Newfoundland and Labrador, the Gulf of St. Lawrence to the Scotian Shelf and the Bay of Fundy (Figure 4; Bigelow and Schroeder 1948; Scott and Scott 1988). Its northern range extends to approximately 56°N along the coast, which is slightly farther north than previously reported for this population in Canadian waters (COSEWIC 2004; Simpson and Miri 2012). The Porbeagle population in the Northwest Atlantic is widely distributed and is described as being most abundant off the east coast of Canada between the Gulf of Maine and Newfoundland and Labrador (Templeman 1963). Experimental longline fishing in the 1960s found that most of the population was concentrated in Canadian waters north of 41°N (Cassoff *et al.* 2007). In Canadian waters, all life history stages of Porbeagle are most abundant on or near the continental shelf, despite the presence of some individuals in international waters to the east (Campana *et al.* 2012). It is thought that approximately 80-90% of the biomass occurs in Canadian waters (Campana pers. comm. 2012).

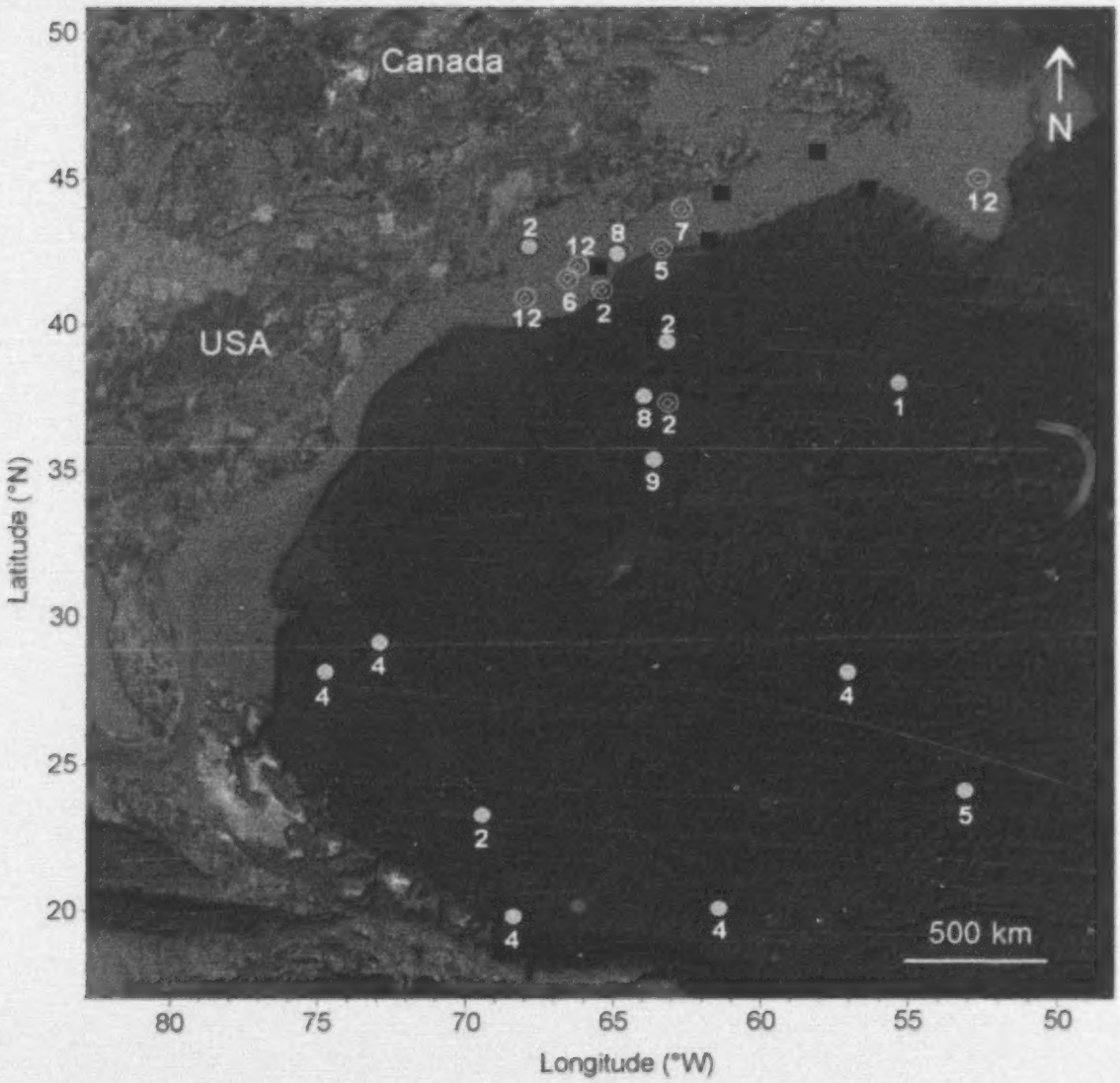

Figure 3. Map showing tagging (black squares) and pop-up locations for 21 Porbeagle sharks tagged off the eastern coast of Canada. Males (solid green circles) and immature females (open pink circles with centres) stayed north of latitude 37°N, whereas all mature females (solid pink circles) with spring pop-up dates migrated to the Sargasso Sea by April. Month of pop-up is indicated by the number. Reprinted with permission from Campana *et al.* (2010).

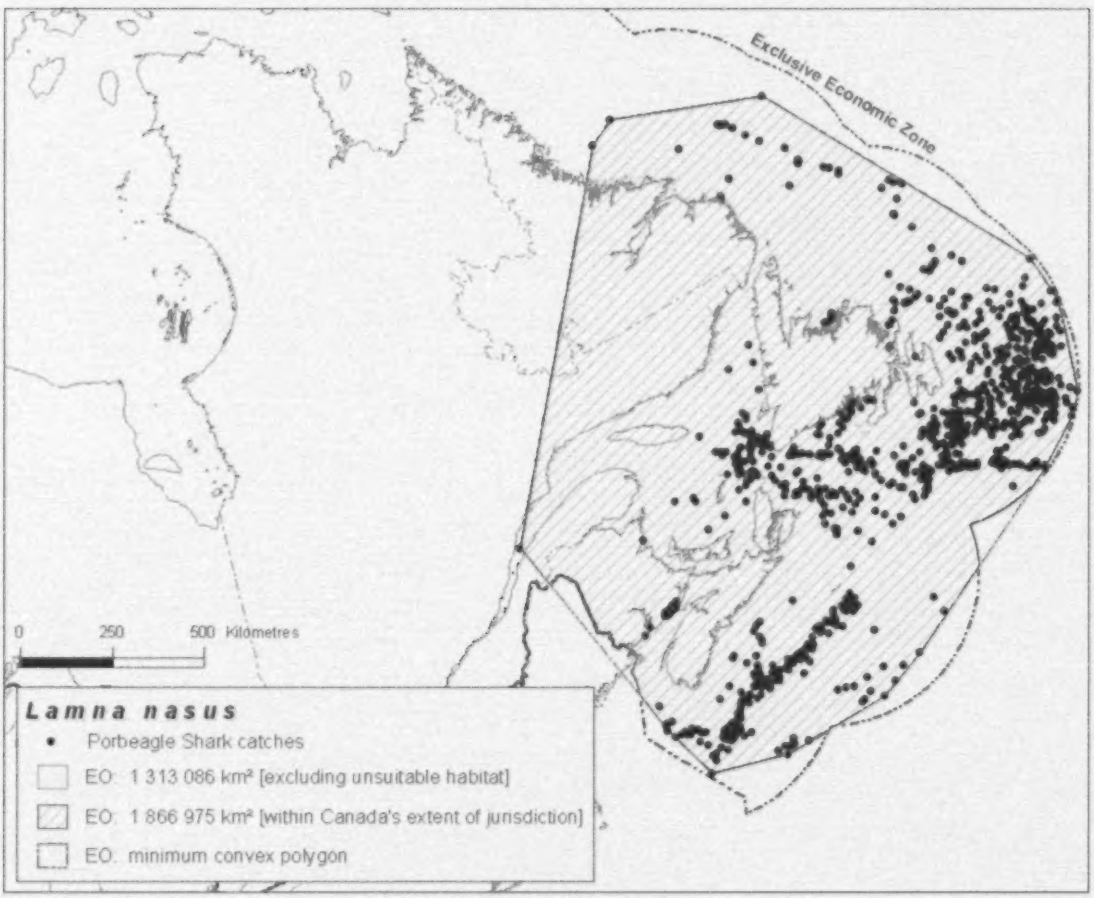

Figure 4. Extent of occurrence (EO) of Porbeagle in Canadian waters, with and without excluding unsuitable habitat (based on the extent of capture locations). At least 15 records of Porbeagle have been observed in the Gulf of St. Lawrence and Estuary. Most of these records are capture locations of fishery landings and observer data provided by Campana *et al.* (2012) and Simpson and Miri (2013), and some are from fishery-independent surveys and satellite tracking data.

Extent of Occurrence and Area of Occupancy

The extent of occurrence (EO) of Porbeagle in Canadian waters is 1,866,975 km^2 (Figure 4). When excluding land, the EO is 1,313,086 km^2. These values are larger than the EO calculated for Porbeagle in its previous COSEWIC assessment, which was 1,212,000 km^2 (COSEWIC 2004). The index of area of occupancy (IAO) was estimated as the surface area of grid cells (2 km x 2 km) that intersect the mating grounds plus the capture locations of gravid females (Figure 5). IAO was estimated as 77,576 km^2 (based on 19,394 grids). EO and IAO were calculated based on capture locations from fisheries data. It is important to note that IAO is likely an underestimate as it is only based on the grid cells where Porbeagle has been caught, and the fishery did not cover the entire extent of the species' distribution.

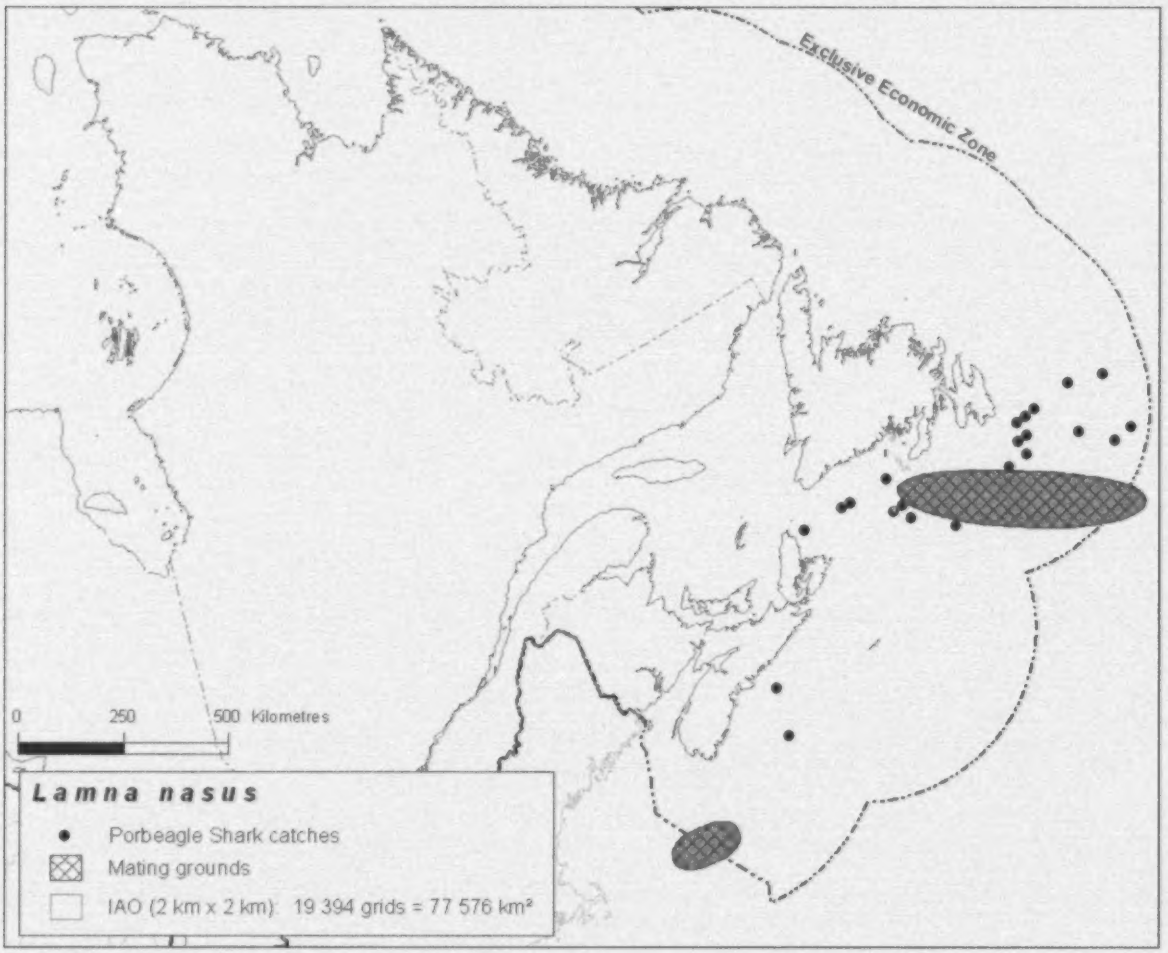

Figure 5. Index of area of occupancy (IAO) of Porbeagle calculated from 19,394 2 km x 2 km grid cells in areas representing Porbeagle mating grounds (southern Newfoundland and Labrador and Georges Bank). Symbols indicate capture locations of gravid females (Campana *et al.* 2012). Note that IAO is likely an underestimate as it is only based on the grid cells where Porbeagle has been caught, and the fishery did not cover the entire extent of the species distribution.

Search Effort

The main sources used to estimate the Canadian range and calculate EO and IAO for Porbeagle were Campana *et al.* (2012) and Simpson and Miri (2013). Campana *et al.* (2012) provided catch locations in the Northwest Atlantic from fishery-independent shark surveys and from the commercial fishery. The shark surveys were carried out in 2007 and 2009 by Atlantic Canadian fishers and scientists from Fisheries and Oceans Canada (DFO). They included 50 stations in the Northwest Atlantic from the Canada-US border to Newfoundland and Labrador, and covered an area of more than 200,000 km^2 (Campana *et al.* 2012). The objective of the surveys was to provide a baseline for monitoring the abundance and population health of Porbeagle in the Northwest Atlantic,

with subsequent surveys to be carried out using the same design (Campana *et al.* 2012). In 2007, 865 Porbeagle sharks were caught throughout the survey area (Campana *et al.* 2012).

Simpson and Miri (2013) provided updated catch information for Porbeagle in Newfoundland and Labrador waters. This included catch locations from fishery-independent surveys (conducted since 1946) and from fisheries observers deployed from the Newfoundland and Labrador region.

Other sources used to define the range and occurrence of Porbeagle in Canada were Campana *et al.* (2010) and Pratt (2012), as well as the Atlantic Canadian Conservation Data Centre, the New Brunswick Museum and Parks Canada. Campana *et al.* (2010) provided location information for 21 Porbeagle that were tracked with satellite tags in the Northwest Atlantic between 2001 and 2008. Pratt (2012) provided catch locations for 87 Porbeagle that were landed in a recreational catch and release fishery in the Bay of Fundy in the summers of 2008-2010. The Atlantic Canada Conservation Data Centre provided three DFO trawl records of Porbeagle (out of 484,633 records), and the New Brunswick Museum collection also provided three records. Parks Canada reported at least 15 accounts of Porbeagle in the St. Lawrence Gulf and Estuary (Paradis pers. comm. 2012), as documented by the Greenland Shark and Elasmobranch Education and Research Group.

HABITAT

Habitat Requirements

Porbeagle occurs in pelagic, epipelagic or littoral habitats (Compagno 2001). It is most commonly observed on continental shelves, but it is also known to occur far from land or occasionally close to shore (Scott and Scott 1988; Compagno 2001). In Canadian waters, Porbeagle are most commonly observed in deep basins and on the edge of the continental shelf (Campana *et al.* 2012). In Argentina, an individual was caught at the mouth of a brackish estuary (Lucifora and Menni 1998), but this species does not enter freshwater (Compagno 2001). Campana *et al.* (2010) recorded a mature female diving to 1360 m, which is among the deepest dives recorded for a pelagic shark.

Porbeagle prefer water temperatures cooler than 18°C (Compagno 2001), and in the Northwest Atlantic, most are caught at temperatures between 5-10°C (mean: 7.4°C; Campana and Joyce 2004). In the spring, Porbeagle associate with a frontal edge that separates cool shelf waters from warmer offshore waters, but they do not associate with fronts in the fall, despite similar temperatures (Campana *et al.* 2012). A recent study encountered Porbeagle in a summer recreational catch and release fishery in the Bay of Fundy, with sharks showing habitat preference for a ridge along the New Brunswick coastline (Pratt 2012). In Canadian waters, Porbeagle are seldom captured at the surface or at depths greater than 200 m, and they appear to live and feed at depths roughly comparable to that of the thermocline (Campana and Joyce 2004). Depth and temperature use of Porbeagle in the Northwest Atlantic is similar to that of Porbeagle in the Northeast Atlantic (Pade *et al.* 2009; Saunders *et al.* 2011).

In the Northwest Atlantic, mating grounds for Porbeagle include the Grand Banks off southern Newfoundland and Labrador and the entrance to the Gulf of St. Lawrence, as well as Georges Bank (Figure 5; Jensen *et al.* 2002; Campana *et al.* 2012). Mating occurs at these locations in the summer and early fall (Jensen *et al.* 2002). Porbeagle pupping grounds are located in the Sargasso Sea (Figure 3), with mature females migrating there in the winter to give birth in the spring (Campana *et al.* 2010). Mature females migrate to the Sargasso Sea at a mean depth of 489 m, which suggests that they are diving below the current and flow of the Gulf Stream, allowing themselves to maximize their net swimming speed and minimize their ambient temperature (Campana *et al.* 2010). Porbeagle young-of-the-year are first captured off the coast of Canada in July (Natanson *et al.* 2002), which suggests that the Gulf Stream aids in the return transport of young sharks north (Campana *et al.* 2010). Unlike mature females, mature males and immature sharks of both sexes appear to remain in waters north of 38°N (Campana *et al.* 2010).

Habitat Trends

Trends in habitat for Porbeagle are not known, but there is little evidence to suggest that suitable habitats have decreased or deteriorated. A wide distribution, opportunistic diet and long migrations suggest that Porbeagle is a flexible and adaptable species.

BIOLOGY

The biology of Porbeagle has been well studied throughout its range. A useful and recent review of Porbeagle biology is available in Francis *et al.* (2008). A summary of biology and life history characteristics in the Northwest Atlantic can be found on the Canadian Shark Research Laboratory website (http://www.marinebiodiversity.ca/shark/english/skull1.htm).

Life Cycle and Reproduction

Porbeagle is a large shark with slow growth, late maturity and low productivity (Cortés 2000, 2002). In the Northwest Atlantic, the mating season extends from September to November (Aasen 1963; Pratt 1993; Jensen *et al.* 2002). Birth occurs in late winter or early spring after an 8-9 month gestation period (Aasen 1963; Francis and Stevens 2000; Jensen *et al.* 2002). Porbeagle do not appear to have an extended latency period (Jensen *et al.* 2002; Campana *et al.* 2012). Therefore, the reproductive cycle is considered to be one year.

Porbeagle have low fecundity and in the Northwest Atlantic litter size ranges from 2-6 pups (average: 3.9 pups; Jensen *et al.* 2002). They are aplacental, viviparous and oophagous, with embryos consuming unfertilized eggs after absorbing their own yolk (Shann 1911, 1923). Size at birth is thought to be similar to that of Porbeagle in the Southwest Pacific (~58-67 cm fork length or FL; Francis and Stevens 2000; Jensen *et al.* 2002).

Growth is similar in both sexes up to the age of maturity, at which time growth slows. In the Northwest Atlantic, males mature at 160-190 cm fork length (FL), while females mature at 205-230 cm FL (Jensen *et al.* 2002). Length and age at 50% maturity is 174 cm FL and 8 years for males, and 217 cm FL and 13 years for females (Jensen *et al.* 2002; Natanson *et al.* 2002). Females become larger than males (Campana *et al.* 2001). Cassoff *et al.* (2007) reported significant differences in growth and age and length at maturity between sharks sampled from the virgin population (years: 1961-1966) and the exploited population (years: 1993-2004). In the years following exploitation, Porbeagle were found to have an increased growth rate and decreased age at maturity, suggesting a compensatory density-dependent growth response (Cassoff *et al.* 2007). Porbeagle have rapid growth in their first year and would recruit into the fishery at age 0-1 in the Northwest Atlantic (Campana *et al.* 2001). Porbeagle in the Southwest Pacific mature at substantially smaller lengths than in the Northwest Atlantic (Francis *et al.* 2008).

Age estimation for Porbeagle in the Northwest Atlantic has been validated up to 26 years, which was based on a 264 cm FL individual (Campana *et al.* 2002a). Indirect methods using the von Bertalanffy growth curve and estimates of natural mortality indicate that Porbeagle may live for more than 40 years (Natanson *et al.* 2002). Natural mortality has been estimated as 0.10 for immature Porbeagle of both sexes, 0.15 for mature males and 0.20 for mature females (Campana *et al.* 1999, 2001).

Generation time, which is the average age of parents in the current cohort, is estimated as the age at which 50% of the females are mature + 1/M, where M is the instantaneous rate of natural mortality. Therefore, generation time is 18 years (13 + 1/0.2).

Physiology and Adaptability

Porbeagle is a warm-blooded shark, with a rete mirabile, a vascular heat exchange mechanism that allows the retention of metabolically generated heat (Carey and Teal 1969). By conserving metabolic heat, Porbeagle are able to maintain body temperatures around 7-10°C higher than ambient water temperature, allowing them to operate efficiently in cold water (Carey and Teal 1969; Carey *et al.* 1971). They may have evolved to take advantage of their thermoregulating capability by preying on abundant cold-water prey in the absence of non-thermoregulating competitors (Campana and Joyce 2004).

Dispersal and Migration

In the Northwest Atlantic, several tagging studies have found that Porbeagle move moderate distances along the continental shelf (up to 1,500 km), with only one individual moving about 1,800 km off the shelf and into the mid-Atlantic Ocean (Francis *et al.* 2008). Satellite tracking studies have generated similar results (Campana *et al.* 2010; Pratt 2012), though mature females have been found to migrate much longer distances of up to 2,356 km (Campana *et al.* 2010).

Porbeagle undertake extensive, annual migrations in the Northwest Atlantic, with the same migratory pattern reproducible from year to year (COSEWIC 2004). They first appear in the Gulf of Maine, around Georges Bank and the southern Scotian Shelf in January and February, move northeast along the Scotian Shelf and offshore basins through the spring and then appear off the southern coast of Newfoundland and Labrador and in the Gulf of St. Lawrence in the summer and fall (Campana *et al.* 1999, 2012). Catches in the late fall indicate a return movement to the southwest (Campana *et al.* 1999, 2012). Gravid females are present on the Scotian Shelf and Grand Banks from September to December, but are not seen from January to June due to their annual migration south to pupping grounds in the Sargasso Sea (Jensen *et al.* 2002; Campana *et al.* 2010). Porbeagle are also thought to move into deeper water in the late fall, and have been caught off the continental shelf, in deep water basins and in the Gulf of Maine in winter (O'Boyle *et al.* 1996). Seasonal migrations and movement patterns appear to be related to temperature, as well as to mating and pupping seasons.

Interspecific Interactions

Porbeagle is an opportunistic piscivore that feeds on a wide variety of pelagic, epipelagic and benthic species (Joyce *et al.* 2002). The most comprehensive diet study on Porbeagle in the Northwest Atlantic examined the stomachs of 1,022 individuals and identified 21 prey species from 20 families. Teleosts made up 91% of diet by weight, while cephalopods were the second most important food item, occurring in 12% of stomachs. In the spring when individuals are located on the Scotian Shelf, their diet is dominated by pelagic fish and cephalopods. In the early fall when individuals move closer inshore to shallower waters of the Grand Banks and the Gulf of St. Lawrence, the amount of groundfish in their diet increases.

In the Bay of Fundy, 71% of 35 Porbeagle hosted the parasitic copepod *Echthrogaleus coleoptratus* (Pratt *et al.* 2010).

POPULATION SIZES AND TRENDS

Sampling Effort and Methods

Population size and trends of Porbeagle in the Northwest Atlantic have been estimated using a forward-projecting, age- and sex-structured life history model (Campana *et al.* 2001; Harley 2002; Gibson and Campana 2005; Campana *et al.* 2012). Data included in the model were total landings, catch-per-unit-effort (CPUE) indices for immature and mature sharks, length-frequency composition of the landed catch, and tagging information (Campana *et al.* 2012). Total landings were those reported by all countries in the Northwest Atlantic to the Northwest Atlantic Fisheries Organization (NAFO) in Subareas 2-6 from 1961 to 2008 (Appendix 1). Discard and post-release mortality estimates were not included in the model. Landings were apportioned to three separate areas because of spatial and temporal differences in the size composition of the catch (Harley 2002; Campana *et al.* 2012). These areas were the NL-Gulf (Gulf of St. Lawrence, the area north of Laurentian Channel and NAFO Subdivision 4Vn east of Cape Breton Island, Figure 6), the Basin (basins and inshore regions of the Scotian Shelf), and the Shelf-Edge (area around the edge of the Scotian Shelf plus the Gulf of Maine). CPUE indices were based on Porbeagle-directed longline landings, which account for virtually all historical landings. Porbeagle CPUE was calculated both on the basis of weight per hook (which was used to calibrate the population model), and separately for the numbers of mature and immature sharks per hook (Figure 7; Campana *et al.* 2012). The CPUE time series was standardized and integrated into the model to correct for differences in timing and gear used (Campana *et al.* 2012). Several models were considered, and the best fit (according to the Akaike Information Criterion) was obtained using a model with separate catchability coefficients for each vessel, in each area and in each season (Gibson and Campana 2005; Campana *et al.* 2012).

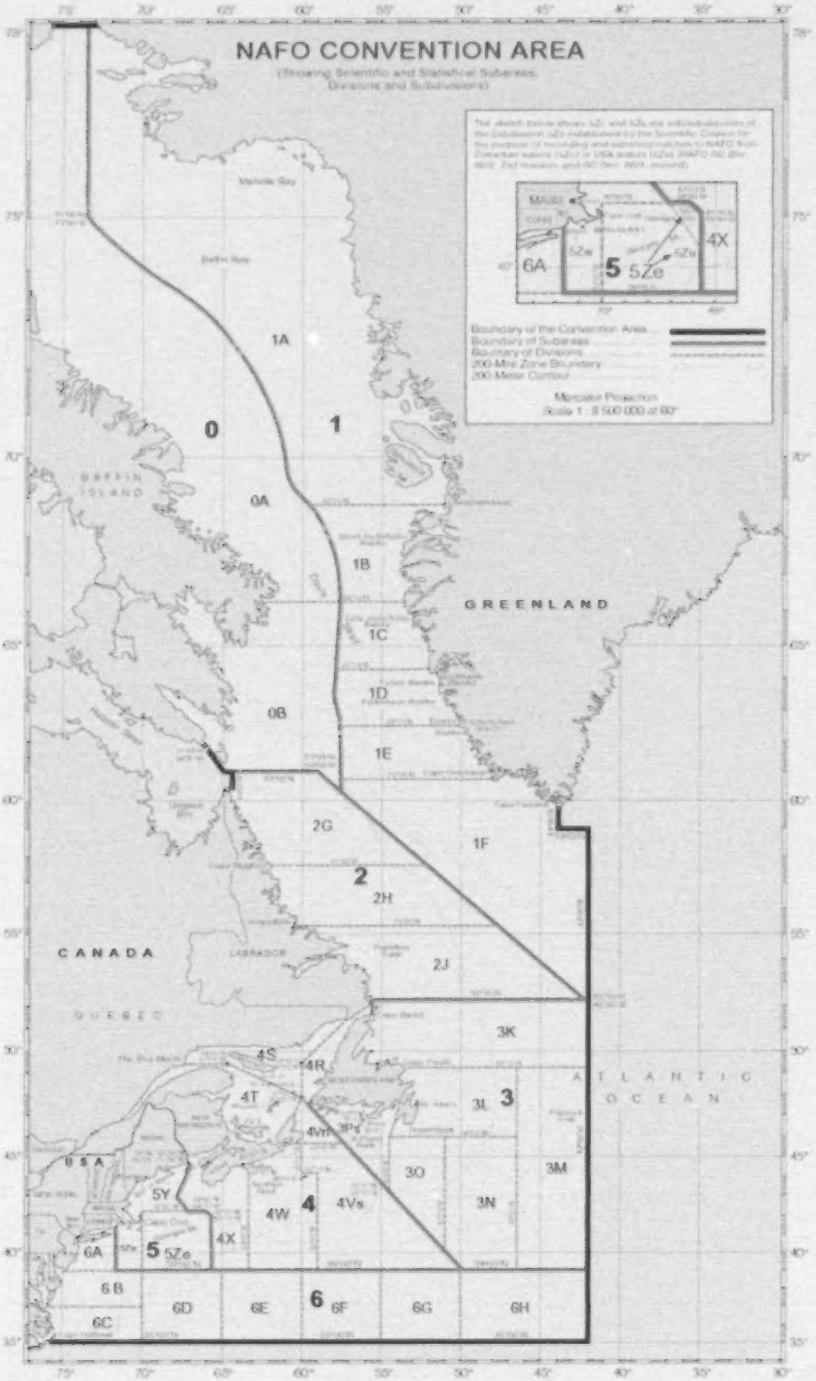

Figure 6. Map of NAFO Divisions in relation to Canada's 200-mile Exclusive Economic Zone boundary (from NAFO).

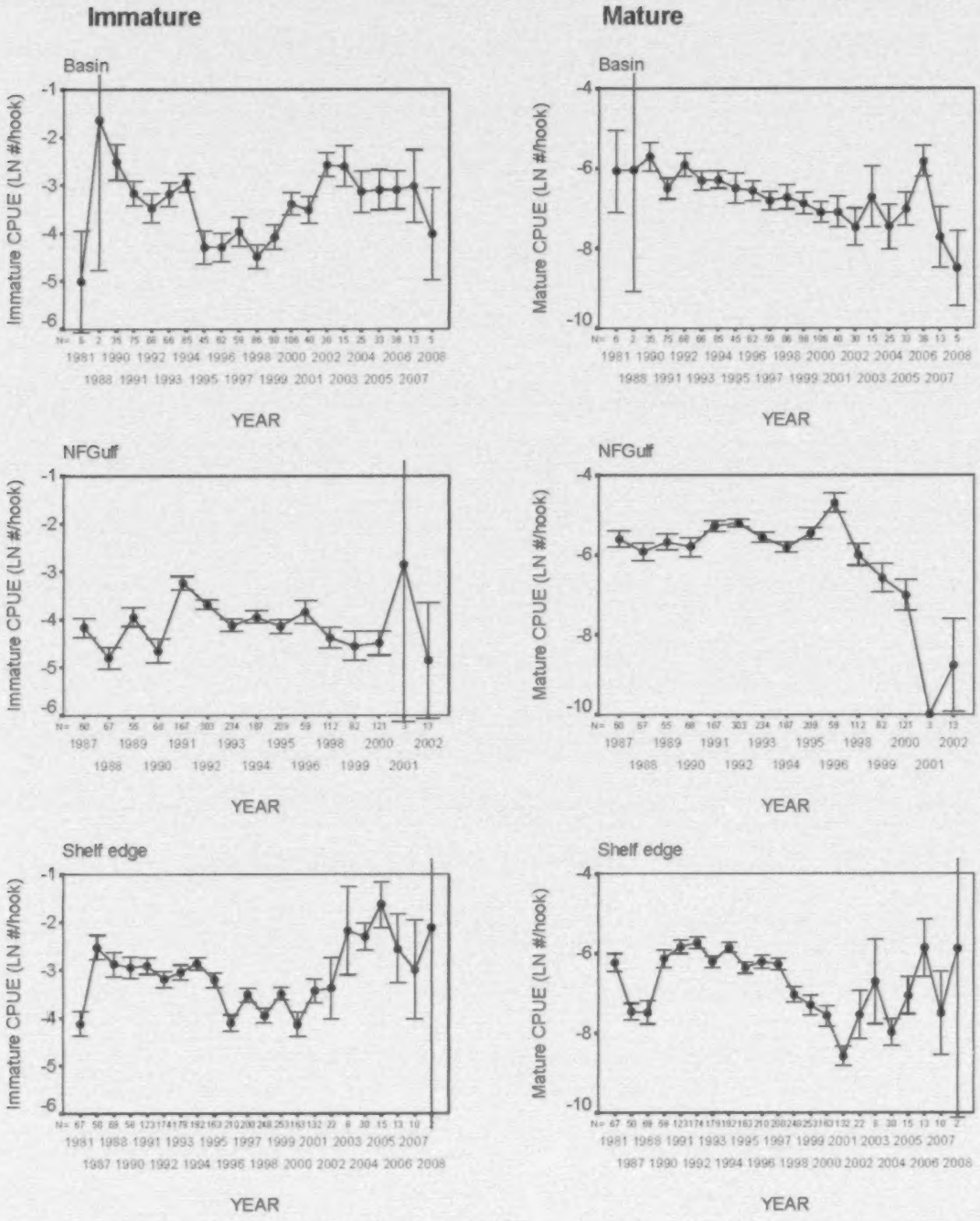

Figure 7. Error bar plots (mean and 95% confidence intervals) showing Porbeagle CPUE by area and maturity stage in terms of ln-transformed number/hook. Note the years differ between graphs. Reprinted with permission from Campana *et al.* (2012).

In the model, the population was projected forward from an equilibrium starting abundance and age distribution by adding recruitment and removing landings (Campana *et al.* 2012). A key assumption was that the Porbeagle population was at an unfished equilibrium at the beginning of 1961, which was when the directed commercial fishery for Porbeagle began. Model parameter estimates, such as selectivity parameters and catchability coefficients, were obtained by fitting the model to the available datasets using maximum likelihood (Campana *et al.* 2012).

Two uncertainties of the model were that (1) estimation of natural mortality was confounded with estimation of selectivity and (2) none of the models achieved a robust fit, meaning there were no measures of uncertainty to qualify the data (Campana *et al.* 2012). Therefore, four model variants were presented by Campana *et al.* (2012), all of which differed in their assumed productivity, to represent different scenarios. Productivity (i.e. α) was defined as the slope at the origin, which in the deterministic model is the annual relationship between female spawners and recruits, or the maximum rate at which female spawners can produce age-1 recruits at low population sizes (Myers *et al.* 1999). Model 1 had an estimated productivity (~3.6), but Models 2-4 had a fixed productivity based on life history characteristics. Productivity values were 2 in Model 2 (lower), 2.5 in Model 3 (intermediate) and 3.2 in Model 4 (higher). These values were thought to span the range of probable Porbeagle productivity based on life history characteristics (Campana *et al.* 2012). Based on maximized likelihoods, Model 1 appeared to be the most plausible scenario, followed by Model 4, with Model 2 being the least plausible (Campana *et al.* 2012).

Reference points were estimated from the model (Campana *et al.* 2012), such as the fishing mortality rate that produces maximum sustainable yield (F_{msy}) or that drives the population to extinction (F_{col}). The model was also used to evaluate potential recovery trajectories and timelines given various management options and exploitation rates. Note that any recovery targets or reference points mentioned in this report are in regards to fisheries targets, not conservation targets.

Abundance

Estimated population size of Porbeagle in the Northwest Atlantic in 2009 ranged from 196,911-206,956 sharks depending on the model (Table 1; Campana *et al.* 2012). The estimated number of spawning females ranged from 11,339-14,207 sharks among the 4 models, or about 6% of the total population (Campana *et al.* 2012). The models indicated that the 2009 population is at about 22-27% of its size in 1961 and 95-109% of its size in 2001, with spawning female abundance at about 12-16% of 1961 levels and 83-103% of 2001 levels (Campana *et al.* 2012). Total population biomass was estimated to be around 10,000 metric tonnes (t) in 2009, placing the 2009 value at 20-24% of the 1961 value and 104-122% of the 2001 value (Campana *et al.* 2012).

Table 1. Estimates of spawning female abundance (SFN) and total population abundance (N) by year obtained from the four models fit to Porbeagle data. From Campana *et al.* (2012).

	Model 1		Model 2		Model 3		Model 4	
Year	SFN	N	SFN	N	SFN	N	SFN	N
1961	71858	760620	86447	915048	79722	843866	73838	781582
1962	70398	724557	85227	877843	78424	807113	72452	745310
1963	67657	671014	82898	822375	75959	752425	69838	691436
1964	61379	553681	77528	700937	70286	632648	63834	573387
1965	51009	387974	68555	530187	60827	463948	53855	406769
1966	41668	307139	60241	448183	52131	382609	44764	325811
1967	34701	290759	53526	431292	45305	366282	37855	309646
1968	29639	306840	48034	444711	39942	381091	32692	325615
1969	24867	304562	42560	440548	34697	378099	27753	323422
1970	20788	297350	37519	431220	29988	370059	23454	316271
1971	17439	291174	33087	422212	25947	362599	19868	310002
1972	14790	291883	29405	419030	22653	361326	17001	310380
1973	12712	290825	26455	413907	20037	358161	14739	308926
1974	11235	287867	24404	406990	18206	353145	13134	305554
1975	10530	287925	23567	403304	17419	351252	12384	305197
1976	10728	284482	24077	396814	17817	346285	12626	301428
1977	11842	277123	25773	387016	19315	337778	13852	293816
1978	13729	272977	28231	380654	21603	332604	15871	289422
1979	16112	276039	30934	381371	24246	334521	18352	292174
1980	18450	279657	33263	382093	26643	336605	20734	295337
1981	20482	284362	35013	383292	28561	339358	22759	299446
1982	22153	293079	36203	388045	29988	345811	24382	307469
1983	23350	304893	36801	395483	30861	355097	25503	318515
1984	23954	317026	36769	402859	31113	364468	26018	329817
1985	24089	330796	36266	411592	30890	375311	26058	342717
1986	23751	341865	35342	417397	30223	383327	25629	352886
1987	23113	350038	34191	420200	29298	388392	24911	360152
1988	22309	353019	32959	417839	28258	388295	24039	362240
1989	21605	353904	31899	413519	27361	386192	23278	362260
1990	21102	352393	31097	407003	26697	381821	22727	359925
1991	20935	347711	30661	397555	26385	374428	22516	354463
1992	20342	326215	29848	371532	25680	350363	21902	332225
1993	19223	298943	28536	340072	24466	320729	20778	304286
1994	18404	282670	27471	320080	23515	302385	19938	287468
1995	17648	261331	26416	295351	22593	279165	19147	265652
1996	16487	247655	24914	278409	21241	263675	17944	251537
1997	15511	237495	23526	265231	20030	251846	16907	241000
1998	14305	221276	21867	246095	18564	233998	15630	224410
1999	13120	210158	20188	232187	17095	221324	14363	212955
2000	12136	199455	18686	218800	15812	209116	13289	201926
2001	10999	190024	17031	206680	14377	198163	12062	192162
2002	10239	187734	15764	201796	13325	194408	11210	189559
2003	9735	190978	14782	202369	12545	196128	10618	192466
2004	9477	194669	14085	203234	12033	198173	10277	195754
2005	9422	195477	13630	200981	11746	197152	10144	196060
2006	9590	196501	13431	198668	11701	196143	10241	196484
2007	9973	198019	13475	196514	11887	195390	10559	197295
2008	10560	202488	13739	196923	12287	197320	11086	200944
2009	11339	206956	14207	196911	12886	198970	11809	204482

There were at least two uncertainties with using CPUE data to derive indices of abundance (Campana *et al.* 2012). First, the spatial distribution of fishing effort decreased markedly in the past decade. Since 2005, almost all landed Porbeagle have been caught along the edge and in the deep basins of the Scotian Shelf, with most fishing activity taking place in the spring (Campana *et al.* 2012). Reductions in the Total Allowable Catch (TAC) resulted in the disappearance of large, offshore vessels from the directed Porbeagle fishery and a major contraction in the area fished (Campana *et al.* 2012). Corresponding with this change was an increase in CPUE after 2002 in the smaller area being fished (Figure 7), suggesting either increased Porbeagle abundance, increased fishing efficiency, a change in the methods being used, or a change in Porbeagle distribution (Campana *et al.* 2012). Second, there is little overlap in the vessels that took part in the fishery in the 1980s and 1990s and those that were fishing in the 2000s (Campana *et al.* 2012). This makes separating year effects from vessel effects difficult, as not all vessels fish with the same efficiency and catchability varies among seasons (Campana *et al.* 2012).

Fluctuations and Trends

Trends in Porbeagle abundance were similar between all model variants (Figure 8; Campana *et al.* 2012). The models indicated a small increase in spawning female abundance in the late 1970s and early 1980s (~1,900-3,400 sharks). The estimated total number of Porbeagle also appeared to increase slightly in the 1980s. Abundance has been relatively stable since 2002 (Campana *et al.* 2012). Although the recent population trajectory is almost flat (Figure 9), the expectation is that spawning abundance will increase due to maturation of juveniles and reduced exploitation (Campana *et al.* 2012).

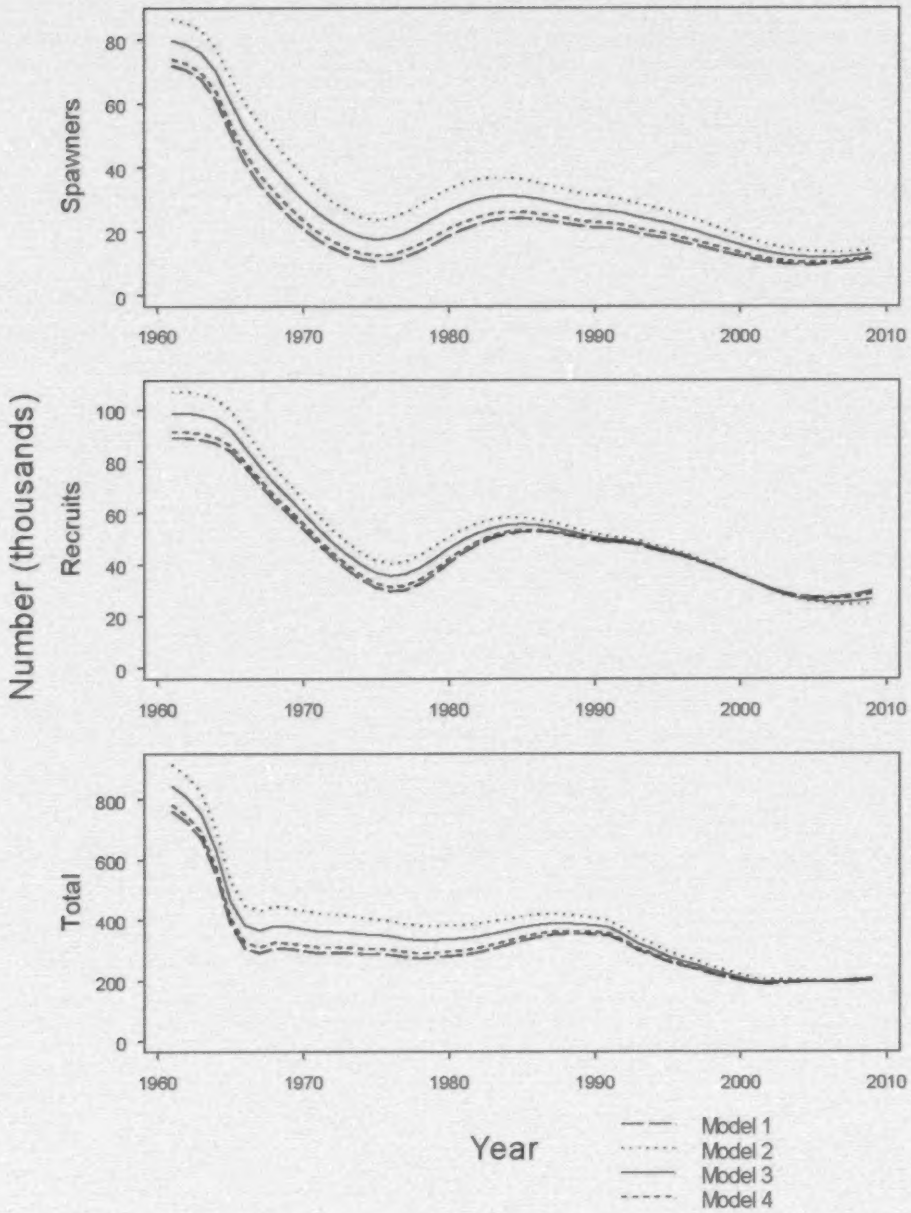

Figure 8. Comparison of the predicted time series of the abundance of spawning females (top), abundance of recruits at age-1 (middle) and total abundance (bottom) from each of the four models fit to Porbeagle data. Reprinted with permission from Campana *et al.* (2012).

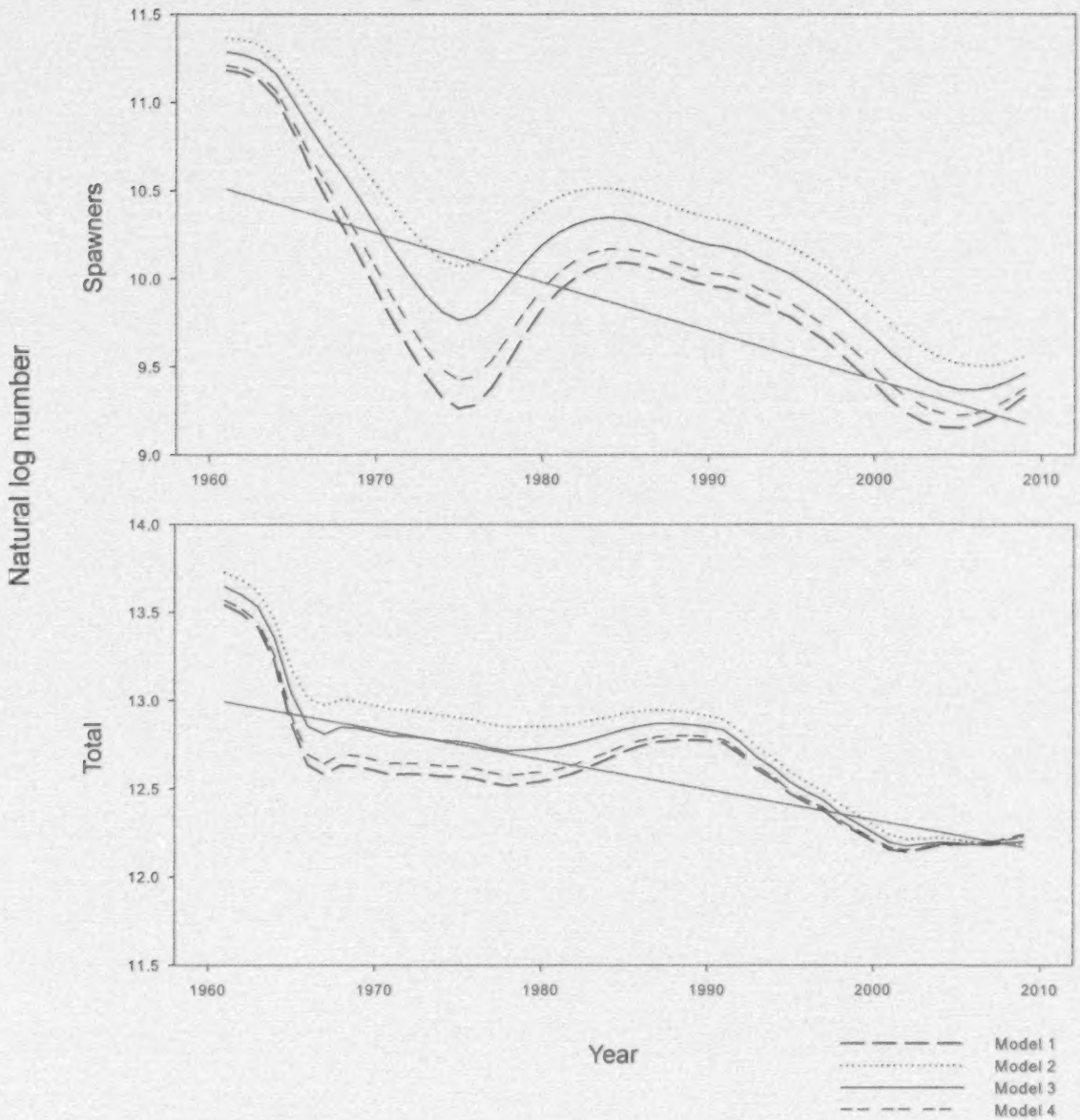

Figure 9. Predicted time series of the logged abundance of spawning females (top) and logged total abundance (bottom) from each of the four models fit to Porbeagle data presented in Campana *et al.* (2012). The regression lines were used to calculate the rates of decline in Table 2.

The percent change in population size was calculated since the beginning of exploitation in 1961 until 2009 (~2.6 generations or 48 years). This calculation was calculated as 100(exp(y b) – 1), where y is the number of years in the time series and b is the slope of the regression. Spawning females declined by 74-77% over this period, and the total population declined by 56-70% (Table 2). These declines appear to have stopped in 2004-2006 (Table 1).

Table 2. Summary table of regression parameters of the logged abundance of all individuals and of spawning females calculated from each of the four models fit to Porbeagle data presented in Campana *et al.* (2012).

					Natural log regression parameters			
Model	Years	Abundance	% Change	N years	R^2	*P*-value	Slope	Intercept
1	1961-2009	Total	-56	48	0.57	<0.001	-0.017	13.01
		Spawners	-74	48	0.51	<0.001	-0.028	10.54
2	1961-2009	Total	-70	48	0.82	<0.001	-0.025	13.40
		Spawners	-77	48	0.76	<0.001	-0.031	11.06
3	1961-2009	Total	-65	48	0.75	<0.001	-0.022	13.24
		Spawners	-76	48	0.68	<0.001	-0.030	10.86
4	1961-2009	Total	-60	48	0.63	<0.001	-0.019	13.08
		Spawners	-74	48	0.57	<0.001	-0.028	10.64

Projections from population models suggest slow rates of recovery on the order of decades if fishing mortality is maintained below 4% of the vulnerable biomass (Campana *et al.* 2012). Caution must be exercised with these predictions, as they depend on mortality rates from directed fishing (currently ceased) and from bycatches in other fisheries (see **THREATS AND LIMITING FACTORS**). There are also numerous biological assumptions in these complex models, including natural mortality rates and productivity of the population. Campana et al. (2012) note: "Unknown, and hence unregulated, catches of Porbeagle on the high seas remain the wild card in the recovery of this population."

Rescue Effect

Porbeagle in the Northwest Atlantic appear to be reproductively independent of the population in the Northeast Atlantic. Thus, there is no rescue potential from fish in the eastern Atlantic. Fish in the Northwest Atlantic undertake extensive movements along the east coast of Canada and the US, and approximately 80-90% of the population occurs in Canadian waters. Thus, it is unlikely that fish from the Canadian side of the population would be rescued from the much smaller number of fish currently restricted to US waters.

THREATS AND LIMITING FACTORS

The life history traits of Porbeagle such as low fecundity, late maturity, slow growth, and low productivity (Cortés 2002; Francis *et al.* 2008), render it vulnerable to overexploitation and limit its capacity to recover from overfishing. Both recruitment overfishing and reduction in spawning stock biomass to the point where recruitment is impaired could occur rapidly in this species (COSEWIC 2004). The population in the Northwest Atlantic has already collapsed twice since the 1960s as a result of overfishing (Campana *et al.* 2008), but population recovery is expected given enough time and correct management (Campana *et al.* 2012).

Porbeagle was first exploited commercially in Atlantic Canada in 1961 by Norwegian vessels that began fishing the virgin population (Figure 10; Appendix 1; Campana *et al.* 2008). Faroese vessels joined in during the next few years. Reported Porbeagle landings in the Northwest Atlantic rose from about 1,900 t in 1961 to over 9,000 t in 1964, and then fell to less than 1,000 t in 1970 as the fishery collapsed (Campana *et al.* 2012). Reported landings remained less than 500 t until 1989 and increased to a high of about 2,000 t in 1992. This was a result of increased fishing effort by Faroese vessels and the entry of Canadian vessels into the fishery (Joyce 1999). Fishing by Faroese vessels in Canadian waters ceased in 1994 and since then, almost all Porbeagle catches were taken by Canadian vessels (Figure 10; COSEWIC 2004). Annual landings were subject to quotas starting in 1998, and have been less than 230 t since 2002 and less than 100 t since 2009. Reduced landings have in part been due to lowering market prices (Campana *et al.* 2012). Only three fishers actively fished for Porbeagle in 2009, one fisher actively fished for Porbeagle in both 2010 and 2011, and there was no directed fishing in 2012. The directed fishery was suspended in 2013 (M. Eagles, DFO Maritimes Region, pers. comm. 2014). There is almost no recreational fishery for Porbeagle. Recent research has documented Porbeagle being caught and released in relatively low numbers in a sport fishery in the Bay of Fundy (Pratt 2012).

A major contraction in the Canadian Porbeagle fishery occurred over time. Until the late 1990s, the fishery consisted of both inshore and offshore vessels that fished on the Scotian Shelf throughout the spring, with the offshore vessels moving to the Gulf of St. Lawrence, around southern Newfoundland and Labrador and on the Grand Banks in the fall (COSEWIC 2004). Starting in the mid-2000s, the fishery consisted of smaller inshore vessels that concentrated mainly on the Scotian Shelf and in some of the basin areas (Campana *et al.* 2012). Although the fishery contracted, the shark survey conducted in 2007 demonstrated that the overall population distribution of Porbeagle had not contracted, and that areas of high Porbeagle density were not restricted to the areas being fished (Campana *et al.* 2012).

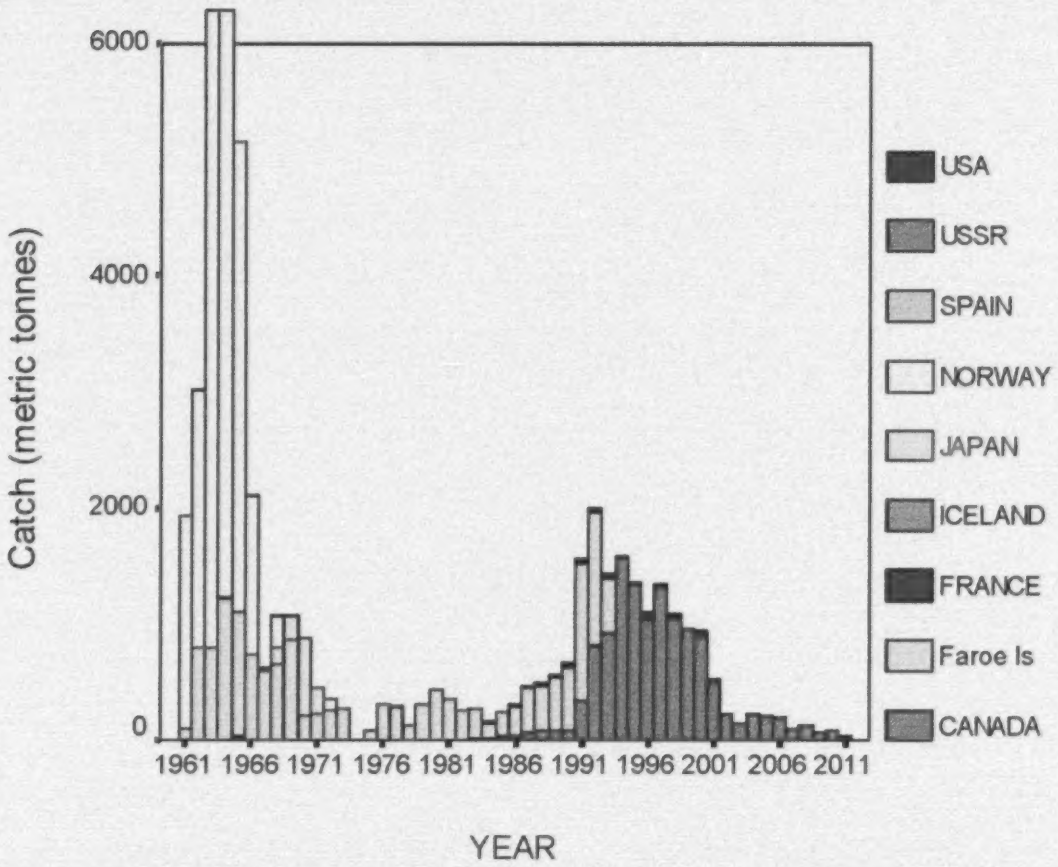

Figure 10. Porbeagle landings in the Northwest Atlantic from 1961 to 2011 (NAFO Subareas 2-6). Reprinted with permission from Campana *et al.* (2012).

There has been very little information available on Porbeagle catches outside Canada (Campana *et al.* 2012). In the US, commercial landings of Porbeagle were around 40 t in 1993 and have been less than 5 t annually since 1999 (NOAA 2011). Mapping of the US observed catches and tag releases and recaptures for 2000-2007 indicated that Porbeagle are found outside Canadian waters in substantial numbers, particularly off the northeastern US and shelf edge east of the Grand Banks (Campana *et al.* 2012). Catches of Porbeagle by the international fleet on the high seas in the Northwest Atlantic appear to remain low, with the proportion in the high seas catch almost always less than 2% (ICCAT/ICES 2009).

In Canadian waters, Porbeagle is taken as bycatch in the swordfish and tuna fisheries, as well as in groundfish fisheries (longline, gillnet and bottom trawl). Campana *et al.* (2011) estimated bycatch for the Scotia-Fundy region by fishery, quarter and year using observations from the Scotia-Fundy Observer Program from 1996-2010. The bycatch proportion was calculated as the weight of discarded Porbeagle relative to the retained targeted catch. During 2000-2011, 52% (371 t) of Porbeagle discards came from the swordfish and tuna longlines and 37% (266 t) from the groundfish otter trawl fishery (Campana *et al.* 2011, 2012). Porbeagle bycatch was mostly limited to the Emerald Basin area and the edge of the Scotian Shelf, and was not spatially representative of the swordfish and tuna fisheries (Campana *et al.* 2011). It was estimated that approximately 29 t of discarded Porbeagle died from fishing-related causes in 2010 and 2011, which was equivalent to about 35% of the reported landings in 2010 and 97% of the reported landings in 2011 (Campana *et al.* 2011, 2012).

Separate to this, Simpson and Miri (2013) estimated Porbeagle bycatch and discards for the Newfoundland and Labrador region using observations from the Newfoundland and Labrador Fisheries Observer Program (NFOP) and methods similar to that of Campana *et al.* (2011). Scaled-up Porbeagle bycatch estimates suggested that a 60 t average had been caught annually in the Atlantic Cod (*Gadus morhua*) gillnet fishery from 1997-2004 (peak of 242 t in 1999), with a Monkfish (*Lophius* spp.) gillnet fishery catching 324 t of Porbeagle in 1994, a White Hake (*Urophycis tenuis*) gillnet fishery catching 18 t in 2009 and a Yellowtail Flounder (*Limanda ferruginea*) bottom otter trawl fishery catching 19 t in 2010 (Simpson and Miri 2013). Porbeagle discards are unrecorded in most of the fisheries statistics, and estimates can only be derived from fishery observer data. Discards have remained relatively constant since 1996 (Figure 11). Discards made up 6% of the catch in 1996. As the targeted catches declined, this percentage increased to 58% in 2009 and 49% in 2010. Discards have been about equal to or greater than landings since 2009. Approximately 100 t of Porbeagle have been discarded annually between 1996 and 2010. Unknown and unreported catch of this magnitude may undermine population recovery. Little is known about Porbeagle catch in fisheries other than a directed fishery, where the catch is landed.

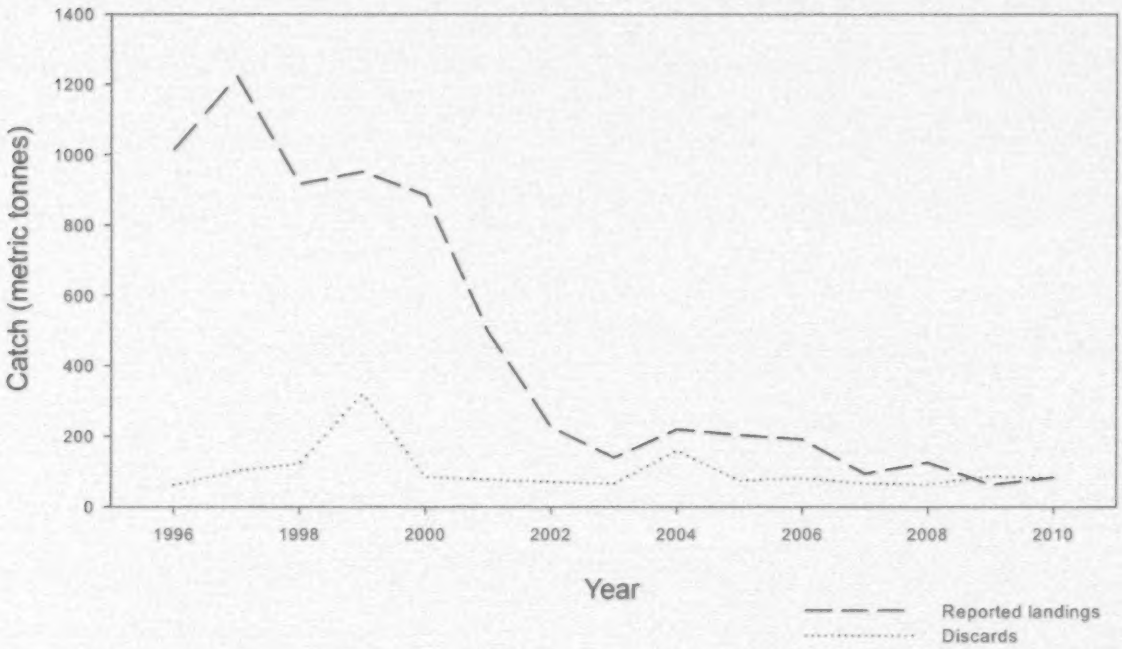

Figure 11. Porbeagle reported landings and estimated discards in Canadian waters from 1996 to 2010. From data in Campana *et al.* (2011, 2012) and Simpson and Miri (2013).

Number of Locations

Porbeagle are highly migratory and distributed continuously throughout their range in the Northwest Atlantic. In Canada, the greatest current threat to Porbeagle is overfishing due to multiple bycatch fisheries, which are not closely monitored, where a large portion of the catch may be discarded and unreported. Therefore, it is difficult to apply the IUCN/COSEWIC definition of number of locations to this species.

PROTECTION, STATUS AND RANKS

Legal Protection and Status

Porbeagle is the only shark species in Canada that is managed with comprehensive stock assessments, and the Canadian Porbeagle fishery may be among the best studied, controlled and monitored of shark fisheries (Godin and Worm 2010). Prior to 1997, fisheries management plans for pelagic sharks in Atlantic Canada established catch guidelines of 1,500 t for Porbeagle, and in 1997-1999 the TAC was reduced to 1,000 t (Campana *et al.* 2012). Starting in 1998, an intensive research program was initiated by DFO to collect detailed information on Porbeagle biology and population dynamics. Stock assessments were conducted using this information, and the Canadian Atlantic Pelagic Shark Management Plan for 2002-2007 reduced the TAC

to 250 t, which was thought to correspond with F_{msy} and allow for stock recovery (Campana *et al.* 2002b; DFO 2002, 2005). In 2005, the TAC was reduced to 185 t based on results of an updated assessment, with the preference that as the TAC limit is approached, any remaining quota be allocated to the bycatch fleet (DFO 2005; Campana *et al.* 2012). Directed-fishing licences for Porbeagle stopped being issued in 2013. Recovery targets have not yet been established for Porbeagle (Campana *et al.* 2012), and there is currently no recovery plan in place for this species. However, the current approach of resource managers, based on the most recent stock assessments, projects a full, albeit slow, population recovery, if anthropogenic mortality remains less than 4% of vulnerable biomass (Campana *et al.* 2012).

In the US, Porbeagle is managed under the Highly Migratory Species Fisheries Management Plan (http://www.nmfs.noaa.gov/sfa/hms/hmsdocument_files/FMPs.htm). Restrictions include trip and gear limits, weight quotas, minimum size landings and finning bans (NOAA 2011). There are also time/area closures for pelagic longliners. Porbeagle was listed as a Species of Concern in 2006 and in 2010 the National Marine Fisheries Service received two petitions to list Porbeagle under the *Endangered Species Act* (ESA). However, neither petition succeeded, so Porbeagle has not been listed on the ESA (NOAA 2011).

There are currently some measures in place for managing Porbeagle fishing in international waters. In 1999, the United Nations Food and Agricultural Organization developed an International Plan of Action (IPOA) for the Conservation and Management of Sharks, which is a voluntary protocol designed to ensure the conservation and management of sharks and their long-term sustainable use (FAO 1999). In cooperation with the IPOA, bodies in the North Atlantic such as the International Council for the Exploration of the Sea, the International Commission for the Conservation of Atlantic Tunas and NAFO have initiated efforts encouraging member countries to collect information about sharks, including Porbeagle (FAO 1999).

In March 2013 at the 16th Conference of the Parties, Porbeagle was accepted for inclusion on Appendix II of CITES (http://www.cites.org/eng/news/pr/2013/20130314_cop16.php), following two previous unsuccessful attempts. DFO is planning to produce its Non-Detriment Findings (NDF) in June 2014, which will examine the science, management and enforcement surrounding the export of the species (Shaw pers. comm. 2014). The implications of the CITES listing will not be known until the NDF is produced.

Non-Legal Status and Ranks

In 2004, COSEWIC assessed Porbeagle as Endangered using criteria A2bd (COSEWIC 2004). It was not listed under the *Species at Risk Act* (SARA) because of economic losses associated with eliminating the directed fishery at the time and prohibiting the sale and trade of Porbeagle caught as bycatch in other fisheries (Government of Canada 2006). In addition, the reduced catch levels were thought to be low enough to avoid jeopardizing the long-term recovery of the species (Government of

Canada 2006). The IUCN lists Porbeagle as Vulnerable (A2bd+3d+4bd) due to its low reproductive capacity and high commercial value of both mature and immature age classes in target and incidental fisheries (Stevens *et al.* 2006).

The population status of Porbeagle has not yet been ranked globally (G rank) or nationally (N rank) in Canada (www.natureserve.org). It also has not been ranked subnationally (S rank) by any Canadian province or territory, except Quebec. Quebec recently changed the subnational rank for Porbeagle from an S4 to an S3S4 (Gauthier pers. comm. 2012), with S4 meaning "apparently secure" and S3 meaning "vulnerable". Porbeagle is likely to be designated as threatened or vulnerable in Quebec (Éditeur officiel du Québec 2010). The current Canadian and Atlantic General Status rank for Porbeagle is 1, meaning that Porbeagle is considered as an At Risk species by the Canadian Endangered Species Conservation Council (CESCC 2006).

Habitat Protection and Ownership

In Canada, the entire range of the species is under the jurisdiction of the federal government. The directed shark fishery was discontinued in 2013, and since 2000, the fishery has remained closed on Porbeagle mating grounds off southern Newfoundland and Labrador in the fall (NAFO Divisions 3LNOP and Subdivision 4Vn, Figure 6; DFO 2002). This closure was thought to play a role in the protection of mating females, as the catch has been largely dominated by immature individuals since the early 2000s (Campana *et al.* 2012).

Existing marine protected areas do not offer any significant protection to this species because they cover less than 1% of the species' range, and individuals are highly migratory. There have been five small marine protected areas (MPAs) established on the east coast of Canada since 2004 that fall within the range of Porbeagle population in the Northwest Atlantic (http://www.dfo-mpo.gc.ca/oceans/marineareas-zonesmarines/mpa-zpm/index-eng.htm). Four of these are along the coastlines of New Brunswick, Prince Edward Island and Newfoundland and Labrador, and are small in size (<100 km^2 total area). The fifth is an area of 2,634 km^2 in the Gully, which is a deep canyon ecosystem at the edge of the Scotian Shelf near Sable Island, about 200 km offshore from Nova Scotia. This larger protected area comprises three management zones, one of which prohibits pelagic longlining. Six additional areas/habitats (coastal and offshore) have been labelled as Areas of Interest for future designation as MPAs along Canada's east coast. Porbeagle has also been documented in the St. Lawrence Estuary in close proximity (a few km upstream) to the Saguenay-St. Lawrence Marine Park, at La Malbaie (Paradis pers. comm. 2012).

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List of Authorities Contacted

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INFORMATION SOURCES

Aasen, O. 1963. Length and growth of Porbeagle (*Lamna nasus*, Bonnaterre) in the North West Atlantic. Fiskeridirektoratets Havforskningsinstitutt 13(6):20-37.

Bass, A.J., J.D. D'Aubrey, and N. Kistnasamy. 1975. Sharks of the east coast of southern Africa. IV. The families Odontaspididae, Scapanorhynchidae, Isuridae, Cetorhinidae, Alopiidae, Orectolobidae and Rhiniodontidae. Investigation Report No. 39. Oceanographic Research Institute, Durban. 102 pp.

Bigelow, H.B., and W.C. Schroeder. 1948. Sharks. Pp. 59-546. *in* Fishes of the Western North Atlantic. Number I. Sears Foundation for Marine Research Memoir.

Branstetter, S. 2002. Mackerel Sharks. Family Lamnidae. Pp. 27-32. *in* B.C. Collette and G. Klein-MacPhee (eds.). Bigelow and Schroeder's Fishes of the Gulf of Maine. Third Edition. Smithsonian Institute Press, Washington D.C.

Campana, S.E. pers. comm. 2012. Scientist, Fisheries and Oceans Canada, Dartmouth, Nova Scotia.

Campana, S.E., and W.N. Joyce. 2004. Temperature and depth associations of Porbeagle shark (*Lamna nasus*) in the Northwest Atlantic. Fisheries Oceanography 13(1):52-64.

Campana, S., L. Marks, W. Joyce, P. Hurley, M. Showell, and D. Kulka. 1999. An analytical assessment of Porbeagle shark (*Lamna nasus*) population in the Northwest Atlantic. Canadian Science Advisory Secretariat Research Document 99/158. Fisheries and Oceans Canada. 58 pp.

Campana, S., L. Marks, W. Joyce, and S. Harley. 2001. Analytical assessment of Porbeagle shark (*Lamna nasus*) population in the Northwest Atlantic, with estimates of long-term sustainable yield. Canadian Science Advisory Secretariat Research Document 2001/067. Fisheries and Oceans Canada. 59 pp.

Campana, S.E., L.J. Natanson, and S. Myklevoll. 2002a. Bomb dating and age determination of large pelagic sharks. Canadian Journal of Fisheries and Aquatic Sciences 59:450-455.

Campana, S.E., W. Joyce, L. Marks, L.J. Natanson, N.E. Kohler, C.F. Jensen, J.J. Mello, H.L. Pratt Jr., and S. Myklevoll. 2002b. Population dynamics of Porbeagle in the Northwest Atlantic Ocean. North American Journal of Fisheries Management 22:106-121.

Campana, S.E., W. Joyce, L. Marks, P. Hurley, L.J. Natanson, N.E. Kohler, C.F. Jensen, J.J. Mello, H.L. Pratt Jr., S. Myklevoll, and S. Harley. 2008. The rise and fall (again) of Porbeagle shark population in the Northwest Atlantic. Pp. 445-461. *in* M.D. Camhi, E.K. Pikitch, and E.A. Babcock (eds.). Sharks of the Open Ocean: Biology, Fisheries and Conservation. Blackwell Publishing, Oxford.

Campana, S.E., W. Joyce, and M. Fowler. 2010. Subtropical pupping grounds for a cold-water shark. Canadian Journal of Fisheries and Aquatic Sciences 67:769-773.

Campana, S.E., J. Brading, and W. Joyce. 2011. Estimation of pelagic shark bycatch and associated mortality in Canadian Atlantic fisheries. Canadian Science Advisory Secretariat Research Document 2011/067. Fisheries and Oceans Canada. 19 pp.

Campana, S.E., A.J.F. Gibson, M. Fowler, A. Dorey, and W. Joyce. 2012. Population dynamics of Northwest Atlantic Porbeagle (*Lamna nasus*), with an assessment of status and projections for recovery. Canadian Science Advisory Secretariat Research Document 2012/096. Fisheries and Oceans Canada. 89 pp.

Canadian Endangered Species Conservation Council (CESCC). 2006. Wild species 2005: the general status of species in Canada. 141 pp.

Carey, F.G, and J.M. Teal. 1969. Mako and Porbeagle: warm-bodied sharks. Comparative Biochemical Physiology 28:199-204.

Carey, F.G., J.M. Teal, J.W. Kanwisher, and K.D. Lawson. 1971. Warm-bodied fish. American Zoologist 11:137-145.

Cassoff, R.M., S.E. Campana, and S. Myklevoll. 2007. Changes in baseline growth and maturation parameters of Northwest Atlantic Porbeagle, *Lamna nasus*, following heavy exploitation. Canadian Journal of Fisheries and Aquatic Sciences 64:19-29.

Compagno, L.J.V. 2001. Sharks of the world: an annotated and illustrated catalogue of shark species known to date. Volume 2. Bullhead, mackerel and carpet sharks (Heterodontiformes, Lamniformes and Orectolobiformes). Food and Agriculture Organization of the United Nations. Rome. 269 pp.

Cortés, E. 1999. Standardized diet compositions and trophic levels of sharks. ICES Journal of Marine Science 56:707-717.

Cortés, E. 2000. Potential rates of increase and rates of increase per generation for three species of pelagic sharks from the Atlantic Ocean. ICCAT Collective Volume of Scientific Papers 51(6):1822-1828.

Cortés, E. 2002. Incorporating uncertainty into demographic modeling: application to shark populations and their conservation. Conservation Biology 16(4):1048-1062.

COSEWIC. 2004. COSEWIC assessment and status report on Porbeagle shark *Lamna nasus* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. viii + 43 pp.

DFO. 2002. Canadian Atlantic pelagic shark integrated fishery management plan 2002-2007. Fisheries and Oceans Canada. 47 pp.

DFO. 2005. Recovery assessment report on NAFO subareas 3-6 Porbeagle shark. Canadian Science Advisory Secretariat Science Advisory Report 2005/043. Fisheries and Oceans Canada. 11 pp.

Duhamel, G., and C. Ozouf-Costaz. 1982. Presence de *Lamna nasus* (Bonnaterre, 1788) aux Iles Kerguelen. Cybium 6(4):15-18.

Éditeur officiel du Québec. 2010. Ministerial Order concerning the establishment of a list of threatened or vulnerable vascular plant species which are likely to be so designated and a list of threatened or vulnerable wildlife species which are likely to be so designated. c. E-12.01. 18 pp.

FAO. 1999. International plan of action for the conservation and management of sharks. Food and Agriculture Organization of the United Nations. Rome. 26 pp.

Fleming, E.H., and P.A. Papageorgiou. 1997. Shark fisheries and trade in Europe. TRAFFIC Europe. Brussels, Belgium. 78 pp.

Fowler, S., C. Raymakers, and U. Grimm. 2004. Trade in and conservation of two shark species, Porbeagle (*Lamna nasus*) and spiny dogfish (*Squalus acanthias*). BfN - Skripten 118. Federal Agency for Nature Conservation. Bonn, Germany. 58 pp.

Francis, M.P., and J.D. Stevens. 2000. Reproduction, embryonic development and growth of Porbeagle shark, *Lamna nasus*, in the South-west Pacific Ocean. Fishery Bulletin 98:41-63.

Francis, M.P., L.J. Natanson, and S.E. Campana. 2008. The biology and ecology of Porbeagle shark, *Lamna nasus*. Pp. 105-113. *in* M.D. Camhi, E.K. Pikitch, and E.A. Babcock (eds.). Sharks of the Open Ocean: Biology, Fisheries and Conservation. Blackwell Publishing, Oxford.

Gauld, J.A. 1989. Records of Porbeagles landed in Scotland, with observations on the biology, distribution and exploitation of the species. Scottish Fisheries Research Report Number 45. 15 pp.

Gauthier, I. pers. comm. 2012. Biologist, Ministère du Développement durable, de l'Environnement, de la Faune et des Parcs du Québec

Gibson, A.J.F., and S.E. Campana. 2005. Status and recovery potential of Porbeagle shark in the Northwest Atlantic. Canadian Science Advisory Secretariat Research Document 2005/053. Fisheries and Oceans Canada. 75 pp.

Godin, C.A., and B. Worm. 2010. Keeping the lead: how to strengthen shark conservation and management policies in Canada. Marine Policy 34:995-1001.

Government of Canada. 2006. Order giving notice of decisions not to add certain species to the list of Endangered species. Canada Gazette Part II. SI/TR/2006-110. September 6, 2006. Web site: http://www.gazette.gc.ca/archives/p2/2006/index-eng.html [accessed July 17, 2013].

Harley, S.J. 2002. Statistical catch-at-length model for Porbeagle shark (*Lamna nasus*) in the Northwest Atlantic. ICCAT Collective Volume of Scientific Papers 54(4):1314-1332.

ICCAT/ICES. 2009. Report of the 2009 Porbeagle stock assessments meeting. ICCAT Collective Volume of Scientific Papers 65(6): 1909-2005.

IUCN Standards and Petitions Subcommittee. 2013. Guidelines for Using the IUCN Red List Categories and Criteria. Version 10. Prepared by the Standards and Petitions Subcommittee. Downloadable from http://www.iucnredlist.org/documents/RedListGuidelines.pdf.

Jensen, C.F., L.J. Natanson, H.L. Pratt Jr., N.E. Kohler, and S.E. Campana. 2002. The reproductive biology of Porbeagle shark (*Lamna nasus*) in the western North Atlantic Ocean. Fishery Bulletin 100:727-738.

Joyce, W.N. 1999. Management of shark fisheries in Atlantic Canada. Pp 74-108. *in* R. Shotton (ed.). Case Studies of the Management of Elasmobranch Fisheries. FAO Fisheries Technical Paper Volume 378. Rome.

Joyce, W.N., S.E. Campana, L.J. Natanson, N.E. Kohler, H.L. Pratt Jr., and C.F.

Jensen. 2002. Analysis of stomach contents of Porbeagle shark (*Lamna nasus* Bonnaterre) in the Northwest Atlantic. ICES Journal of Marine Science 59:1263-1269.

Kato, S., S. Springer, and M.H. Wagner. 1967. Field Guide to Eastern Pacific and Hawaiian Sharks. United States Fish and Wildlife Service Circular 271. 47 pp.

Last, P.R., and J.D. Stevens. 2009. Sharks and Rays of Australia. Second Edition. CSIRO Publishing, Melbourne. 644 pp.

Lucifora, L.O., and R.C. Menni. 1998. First record of a Porbeagle shark, *Lamna nasus*, in brackish waters of Mar Chiquita Lagoon, Argentina. Cybium 22(1):87-88.

Menni, R.C., and A.E. Gosztonyi. 1977. Nuevas localidades para *Raja trachyderma* y *Lamna nasus* (Chondrichthyes, Rajiidae y Lamnidae). Neotropica 23(69):66-68.

Myers, R.A., K. G. Bowen, and N. J. Barrowman. 1999. The maximum reproductive rate of fish at low population sizes. Canadian Journal of Fisheries and Aquatic Sciences 56:2404-2419.

Nakaya, K. 1971. Descriptive notes on a Porbeagle, *Lamna nasus*, from Argentine waters, compared with the north Pacific salmon shark, *Lamna ditropis*. Bulletin of the Faculty of Fisheries Hokkaido University 21(4):269-279.

Natanson, L.J., J.J. Mello, and S.E. Campana. 2002. Validated age and growth of Porbeagle shark (*Lamna nasus*) in the western North Atlantic Ocean. Fishery Bulletin 100:266-278.

NOAA. 2011. Species of concern NOAA National Marine Fisheries Service: Porbeagle *Lamna nasus*. 6 pp.

O'Boyle, R.N., G.M. Fowler, P.C.F. Hurley, M.A. Showell, and W.T. Stobo. 1996. Observations on Porbeagle shark (*Lamna nasus*) in the North Atlantic. DFO Atlantic Fisheries Research Document 96/24. Fisheries and Oceans Canada. 29 pp.

Pade, N.G., N. Queiroz, N.E. Humphries, M.J. Witt, C.S. Jones, L.R. Noble, and D.W. Sims. 2009. First results from satellite-linked archival tagging of Porbeagle shark, *Lamna nasus*: area fidelity, wider-scale movements and plasticity in diel depth changes. Journal of Experimental Marine Biology and Ecology 370:64-74.

Paradis, S. pers. comm. 2012. *Email correspondence to B. Howes.* July 2012. Coordinator, Species at Risk, Parks Canada, Québec City, Québec.

Pratt, H.L. Jr. 1993. The storage of spermatozoa in the oviducal glands of western North Atlantic sharks. Environmental Biology of Fishes 38:139-149.

Pratt, J. 2012. Aspects of the biology of Porbeagle shark (*Lamna nasus*) in the upper Bay of Fundy determined through a recreational catch-and-release fishery. M.Sc. dissertation, University of New Brunswick, Saint John, New Brunswick, Canada. 66 pp.

Pratt, J.D.H., D.F. McAlpine, S.D. Turnbull, and P. Emery. 2010. Prevalence, intensity, and site of infection of *Echthrogaleus coleoptratus* (Guérin-Méneville, 1837) (Siphonostomatoida, Pandaridae), ectoparasitic on Porbeagle shark (*Lamna nasus*) in the Bay of Fundy, Canada. Crustaceana 83(3):375-379.

Rose, D. 1998. Shark fisheries and trade in the Americas. Volume I: North America. TRAFFIC North America. Washington D.C. 143 pp.

Saunders, R.A., F. Royer, and M.W. Clarke. 2011. Winter migration and diving behaviour of Porbeagle shark, *Lamna nasus*, in the Northeast Atlantic. ICES Journal of Marine Science 68(1):166-174.

Scott, W.B., and M.G. Scott. 1988. Atlantic Fishes of Canada. Canadian Bulletin of Fisheries and Aquatic Sciences No. 219. 731 pp.

Shann, E.W. 1911. A description of the advanced embryonic stage of *Lamna cornubica*. Annual Report of the Fishery Board for Scotland 28(3):73-79.

Shann, E.W. 1923. The embryonic development of Porbeagle shark, *Lamna cornubica*. Proceeding of the Zoological Society of London 11:161-171.

Shaw, J. pers. comm. 2014. Science Advisor, Fisheries and Oceans Canada, Ottawa, Ontario.

Simpson, M.R., and C.M. Miri. In press. A pre-COSEWIC assessment of porbeagle shark (*Lamna nasus*) in Newfoundland and Labrador waters. Canadian Science Advisory Secretariat Research Document 2013/088.

Stevens, J.D. 1990. Further results from a tagging study of pelagic sharks in the north-east Atlantic. Journal of the Marine Biological Association of the United Kingdom 70:707-720.

Stevens, J.D., M.C. Dunning, and S. Machida. 1983. Occurrence of Porbeagle shark, *Lamna nasus*, in the Tasman Sea. Japanese Journal of Ichthyology 30(3):301-307.

Stevens, J., S.L. Fowler, A. Soldo, M. McCord, J. Baum, E. Acuña, A. Domingo, and M. Francis. 2006. *Lamna nasus*. *in* IUCN 2012. *2012 IUCN Red List of Threatened Species*. Web site: www.iucnredlist.org [accessed 15 September 2012].

Storai, T., A. Celona, M. Zuffa, and A. De Maddalena. 2005. On the occurrence of Porbeagle, *Lamna nasus* (Bonnaterre, 1788) (Chondrichthyes: Lamnidae), off Italian coasts (northern and central Mediterranean Sea): a historical survey. Annales, Series Historia Naturalis 15(2):195-202.

Svetlov, M.F. 1978. Porbeagle, *Lamna nasus*, in Antarctic waters. Journal of Ichthyology 18:850-851.

Templeman, W. 1963. Distribution of sharks in the Canadian Atlantic (with special reference to Newfoundland waters). Fisheries Research Board of Canada Bulletin No. 140. 77 pp.

Vannuccini, S. 1999. Shark utilization, marketing and trade. FAO Fisheries Technical Paper No. 389. Food and Agricultural Organization of the United Nations. Rome. 470 pp.

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Danielle Knip is a postdoctoral research fellow with the Sea Around Us Project at the University of British Columbia's Fisheries Centre. She is assembling reconstructed fisheries catch data and developing databases for the project, as well as working to improve the spatial precision of global fisheries landings. She completed her PhD in 2011 at James Cook University in Australia, where she conducted a field-based study using acoustic telemetry to track pigeye (*Carcharhinus amboinensis*) and spottail (*Carcharhinus sorrah*) sharks. Using movement data, she defined elements of their ecology, such as how environmental variation affects their home range and use of coastal habitats. She also evaluated the effectiveness of MPAs for sheltering their populations from fishing pressure in coastal regions.

Appendix 1. Reported landings (metric tonnes) of Porbeagle by country for NAFO Subareas 2-6. Canadian landings are converted to live equivalent weight, which differs in some cases from the live weight recorded in the statistics. From Campana *et al.* (2012).

Year	Canada	Faroe Is	France	Iceland	Japan	Norway	Spain	USSR	USA	Total
1961	0	100				1824				1924
1962	0	800				2216				3016
1963	0	800				5763				6563
1964	0	1214		7		8060				9281
1965	28	1078				4045				5151
1966	0	741				1373				2114
1967	0	589			36					625
1968	0	662			137	269				1068
1969	0	865			208					1073
1970	0	205			674					879
1971	0	231			221					452
1972	0	260				87				347
1973	0	269								269
1974	0									0
1975	0	80								80
1976	0	307								307
1977	0	295								295
1978	1	121								122
1979	2	299								301
1980	1	425								426
1981	0	344			3					347
1982	1	259			1					261
1983	9	256			0					265
1984	20	126			1	17				164
1985	26	210			0					236
1986	24	270			5			1		300
1987	59	381			16			0	12	468
1988	83	373			9			3	32	500
1989	73	477			9			3	4	566
1990	78	550			8			9	19	664
1991	329	1189			20			12	17	1567
1992	814	1149			7			8	13	1991
1993	920	465			6			2	39	1432
1994	1573				2				3	1578
1995	1348		7		4				5	1364
1996	1043		40		9				8	1100
1997	1317		13		2		3		2	1337
1998	1054		20		0		9		12	1095
1999	955				6		3		3	967
2000	899		13		24		5			941

Year	Canada	Faroe Is	France	Iceland	Japan	Norway	Spain	USSR	USA	Total
2001	499		2		25		3			528
2002	229		1		0		5		0	236
2003	139		2		0		2		0	143
2004	218		4		0		5		1	228
2005	203						7		0	210
2006	190						9		0	199
2007	93						6			99
2008	125						37			162

Notes:

Northwest Atlantic data for 1950-1960 are from FAO (ICCAT Report of Shark Working Group, Miami, 26 - 28 February 1996), 1964-1986 from NAFO, 1987-2004 from Scotia-Fundy and NF IOP (includes landings and discards), and 2000-2008 from FAO Fishstat Plus v 2.32 Capture Production March 2008, NAFO Database 21B or ICCAT Task 1 Dataset 2009

Canada data for 1961-1990 are from NAFO, 1991-2002 from DFO Zonal Statistics File, corrected to appropriate live equivalent weight, and 2003-2008 from DFO MARFIS

Faroe Island data for 1961-1963 are from FAO (ICCAT Report of Shark Working Group, Miami, 26-28 February 1996)

France data are from FAO Statistics (1998), 2000-2006 from FAO Fishstat Plus v 2.32

Northwest Atlantic data for 2000-2006 (**Japan**) are from NAFO Database 21B, catch for code 469, large sharks

Norway data for 1961-1986 are from NAFO

NAFO catch data for **Spain** for 2005 (231mt) and 2006 (230 mt) were errors, and not reported here

Northwest Atlantic data for **US** from 1961-1994 are from FAO (ICCAT Report of Shark Working Group, Miami, 26-28 February 1996)